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**Virtual Observer Controller (VOC) for Small Unit
Infantry Leader Simulation Training**

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University of Central Florida, Institute for Simulation and Training

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VIRTUAL OBSERVER CONTROLLER (VOC) FOR SMALL UNIT INFANTRY LEADER SIMULATION TRAINING

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INTRODUCTION

This report describes the work done in response to the following Phase II STTR topic:

Develop intelligent, automated coaching and feedback for training dismounted small-unit leaders and teams within a collective virtual simulation/computer gaming environment. The intent is to merge two training technologies – intelligent tutoring engines for individual skill training and virtual/gaming simulations for small-unit, dismounted operations. A synthetic, intelligent “virtual” observer/controller (VOC) shall be created within simulations to perform the real-time coaching and feedback functions similar to those functions executed by actual observer/controllers (O/C) or unit leaders during field exercises within a unit or at the Army’s Combat Training Centers.

This report is comprised of four major sections: Introduction, Methods, Findings, and Discussion. The Introduction section presents a statement of the problem and an operational overview of the Virtual Observer/Controller (VOC). The Methods section describes how the development team produced the VOC and how the instructional effectiveness of the VOC could be evaluated. The Findings section presents a system-oriented description of the VOC. The Discussion section describes the lessons learned and includes a technical discussion about the more challenging aspects of the VOC development effort.

Statement of the Problem

Training using simulated environments has progressed rapidly in recent years due to significant investment by the Department of Defense (DoD), in general, and the Army, in particular. Simulations for small-unit dismounted warrior operations have benefited from recent advances in several technologies. Some of these include increased graphical display resolution and detail in the physical terrain needed for dismounted operations and in modeling and displaying realistic human behavior. These simulation environments can provide immersive, realistic, and engaging experiences. However, in spite of the technological advances, simulation environments are still essentially practice environments. The intervention of a knowledgeable human mentor and the use of sound instructional design of training scenarios are still needed to reduce the possibility of reinforcing poor performance. Even with a human in the loop there will be variations in training effectiveness that are a function of the human trainer’s knowledge of the subject matter and his or her instructional skills.

However, as simulation technologies have advanced, there have been corresponding advances in the development of increasingly sophisticated simulated mentors or coaches in the intelligent tutoring community. These tools include advanced intelligent tutoring technology where software Domain Experts (sometimes referred to as Intelligent Agents) are created to provide automated monitoring and assessment of student performance within a training environment.

The ongoing intelligent tutor developments have enhanced the tutoring capabilities of embedded virtual coaches. Furthermore, there is an increasing body of evidence that suggests that these tutoring systems produce significant improvements in instructional effectiveness and efficiency (e.g., Wisher, McPherson, Thornton, & Dees, 2001).

The VOC represents the integrated application of three different technologies. Sonalysts' ExpertTrain-based intelligent tutoring applications had previously applied intelligent tutoring technologies to provide adaptive training within scenario-based environments (McCarthy, Wayne, & Morris, 2001). ExpertTrain technology forms the basis of the Coach component of the VOC. The Soldier Visualization System (SVS) created by AIS Reality Response had been used extensively for training dismounted Infantry Soldiers in simulated urban environments. The SVS provides the simulation environment into which the VOC was integrated and used. The University of Central Florida's Institute for Simulation and Training developed the Dismounted Infantry Virtual After Action Review System (DIVAARS) to be used in conjunction with the SVS to provide after action reviews (AAR). For the purposes of this research effort the DIVAARS tool was extended to provide an exercise replay and an analytical AAR capability.

The goal of this project was to produce a prototype VOC System that could be evaluated to determine its instructional effectiveness in training small unit dismounted Infantry leaders in simulated urban operations. An instructionally effective system would be expected to make training more readily available and possibly reduce overall training costs. The cost of establishing physical training facilities and bringing Soldiers and trainers together can be significant. A computer-based intelligent tutor environment should be able to provide an opportunity for Soldiers to become skilled with the basic tasks required prior to field training exercises or in combat situations.

VOC Concept of Operations

The capabilities and behaviors of a human observer/controller form the role model for a synthetic or virtual observer/controller and thus provide an important source of requirements for the VOC. The human observer/controller uses his or her knowledge of the rules of engagement, small-unit tactics, techniques, and procedures, common sense, and other heuristics to make valid assessments of the unfolding tactical situation. An effective human observer/controller watches a unit involved in a simulated training exercise and performs continuous tactical and situation assessment as the training progresses. In addition, he forms expectations of appropriate unit behavior and then compares actual unit performance against those expectations.

As training is conducted, the human observer/controller observes the friendly unit make decisions and take actions. At various points during the training exercise, the human observer/controller may come to some conclusion regarding the friendly unit's performance and decide to intervene by providing instruction, such as stopping the

exercise to allow a discussion about what is happening or giving the unit commander some guidance without causing a serious break in the flow of the training execution.

As with a human observer/controller, in order for a VOC to function intelligently, it must know what is happening at any time, and what should be happening at any time. If a VOC is to be an effective mentor, then it must be able to perform situation assessment and also evaluate appropriate Soldier behavior. However, since the VOC cannot perceive the situation and the unit actions with human eyes, it must be informed by the simulation about what is occurring.

In summary, the VOC's basic operations can be described as:

- Provide the tactical context and stimulus,
- Observe the situation,
- Form expectations of behavior,
- Monitor Soldier performance and compare to expectations, and
- Intervene instructionally and record events for AAR use.

More detailed descriptions of the system can be found in the Appendices of this report.

METHOD

This section of the report is divided into two major sub-sections. The first describes the methods used to develop the VOC. The second section describes how the instructional effectiveness of the VOC can be evaluated.

This section of the report provides a process-oriented narrative describing the methods, practices and processes used to develop the VOC. The VOC development process employed a traditional waterfall approach, proceeding through the following primary phases:

- Feasibility Analysis and Preliminary Design,
- Cognitive Model Development,
- Requirements Development,
- System Design,
- Development,
- Testing,
- Deployment to the evaluation environment.

The development of a cognitive model represents a step not normally found in a software development process, but one which is of central importance in the development of an Intelligent Tutoring System such as the VOC. The VOC system is first and foremost a training system. The cognitive model captures the instructional goals of the system and uses them as a hierarchy of learning objectives that represent the top level requirements of the system as a whole. It is essential that the first step in the development process be the preparation of the cognitive model because the requirements for the Coach component functionality are derived directly from the contents of the cognitive model. Other software and system capabilities and requirements will be derived in support of the instructional goals of the system as expressed in the cognitive model, such as the ability to start and stop training exercises and to correlate recorded data with particular user identities. Additional requirements for the VOC are derived from the need to perform an Instructional Effectiveness Evaluation, such as the capture of Soldier performance during training exercises.

The requirements for the Coach component, derived directly from the cognitive model, drive messaging and data requirements. In order for the Coach component to assess any particular Soldier behavior or recognize a significant event in the simulated environment, there must be messages and data provided by the simulation that allow such assessment. Extracting the messaging and data requirements from the cognitive model is done by developing a document called Trigger Analysis (see Appendix A). This analysis describes the messages and data required to support the Coach assessment at a notional level, and is used to develop requirements and prepare a design of the required communications protocol.

An additional difference between the software development process used to develop an Intelligent Tutoring System and that of a more traditional software system is the development and validation of training scenarios. The preparation and validation of scenarios spans several software development phases, beginning with development of the cognitive model and continuing through system testing. It is perhaps not immediately obvious that scenario development should be either complicated or important, but it is both. The scenario events represent the framework used by the simulation environment to establish the tactical context for and assessment of Soldier behaviors. As such, the events must be constructed to establish these contexts according to three sets of constraints:

- The instructional goals of the training system,
- The specific situation assessment processing that has been built into the intelligent tutoring component,
- The limitations of the situation assessment processing embodied in the intelligent components of the system.

First, we will consider how to accommodate the limitations of the situation assessment capability. The specific situations that the Soldier is confronted with in the virtual world must not transfer to the Coaching component any situation that it cannot

adequately assess. For example, if the Coach expects the Soldier to take specific action upon encountering an OPFOR, but then take different actions upon encountering a wounded civilian, then the scenario should provide some reasonable visual clues to the Soldier about the specific situation they have encountered. In the scenario, both events could occur simultaneously. The OPFOR could be detectable to the Soldier conducting the scenario, while the wounded civilian could be also detected. As such, the scenarios must supply opportunities for the Soldier to demonstrate the behaviors reflected in the instructional goals of the system for both events. These goals are embodied in the cognitive model and include the examples just cited.

The last aspect of the VOC development that is quite different from traditional software development projects is the creation of feedback messages. These messages are formulated by the Coach component and delivered to the Soldier in real-time, via the simulation. They describe, in various levels of detail, what the Soldier has done correctly or incorrectly. In addition, variables included within the templates used to construct the messages contextualize the coaching to make it unique to the current situation, such as including the specific room name or unit name. Most learning objectives included in the cognitive model within an ExpertTrain tutor are associated with a target, which is a description of the desired behavior relative to the learning objective. When the Soldier behaves in accordance with the target, we want to reinforce that behavior by providing a metaphorical pat on the back, which would be manifested to the Soldier by the delivery of a positive feedback message. Similarly, some learning objectives are associated with at least one, and possibly several, bugs, which are the typical and predictable errors that Soldiers might make during their performance. When the Soldier behaves in accordance with one of the bugs, we want to correct his performance by delivering remedial coaching that is tailored to his mistake. To accommodate these targets and bugs, we created at least two sets of coaching templates for each learning objective – one set for the target behavior and one set for each of the possible bugs.

When real-time coaching for either targets or bugs is to be delivered, the intent is to do so at an appropriate level of detail and, in general, to say as little as possible to achieve the performance goals. The general rule employed in the Coach is that when a Soldier shows positive mastery on a particular learning objective for which we are about to deliver feedback, then we select a feedback message with a low level of detail. However, when the learning objective indicates inappropriate performance, then we select a higher level of detail message. Thus, the low-level feedback messages are always designed to be as brief as possible, whereas the high-level messages are meant to be more detailed. For example, if we wish to provide feedback regarding a Soldier's performance in acknowledging an order, then we might provide a positive feedback message that simply says "Good acknowledgement." While a higher level of detail negative feedback might say "You should acknowledge orders as quickly as possible" (see Appendix B).

As was discussed in the Introduction of this report, the VOC was constructed through the integration of three pre-existing technologies from three independent development teams. The integration of these systems was accomplished by describing

formal interfaces between each of the components. This allowed for a clean separation of requirements and design and development among system components. The division of labor among the three contractors during the development of the VOC was as follows:

- Sonalysts Inc. was responsible for development of the Coach component of the intelligent tutor that performs situation assessment, evaluates Soldier performance and provides real-time instructional interventions,
- University of Central Florida, Institute for Simulation and Training was responsible for development of enhanced DIVAARS-based AAR component,
- Advanced Interactive Systems' Reality Response was responsible for development of the SVS-based simulation component that hosts the simulated world and has been instrumented to support the exchange of the requisite information with the Coach component.

VOC FUNCTION

VOC System Description

The VOC was developed to provide training for one dismounted Infantry squad leader and two fire team leaders. All other human participants on the battlefield are computer generated forces (CGF) provided by the SVS. The computer configuration required for mission execution includes a personal computer for each participating Soldier. Each PC hosts the SVS simulation and the Coach component. A fourth machine acts as a server hosting the Trainer Control component, DIVAARS and SVS running in Battlemaster mode. This machine also holds the Soldier's performance data, recorded by the Coaches and managed by the Trainer Control component. Figure 1 illustrates this configuration.

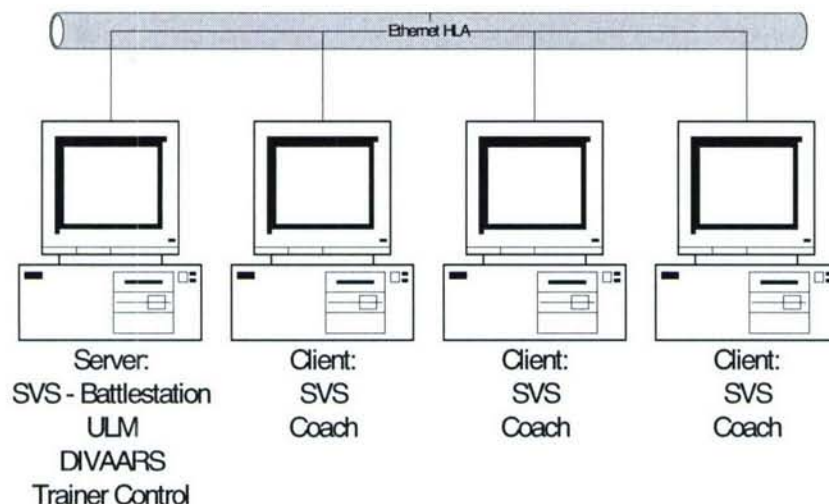


Figure 1 – Hardware Configuration

The major software components of the system are:

- SVS Simulation Environment Component
- Coach: Soldier Performance Assessment and Feedback Component
- DIVAARS: After Action Review Component
- Trainer Management Component (not shown)

Figure 2 shows the major components that comprise the VOC and their general relationship.

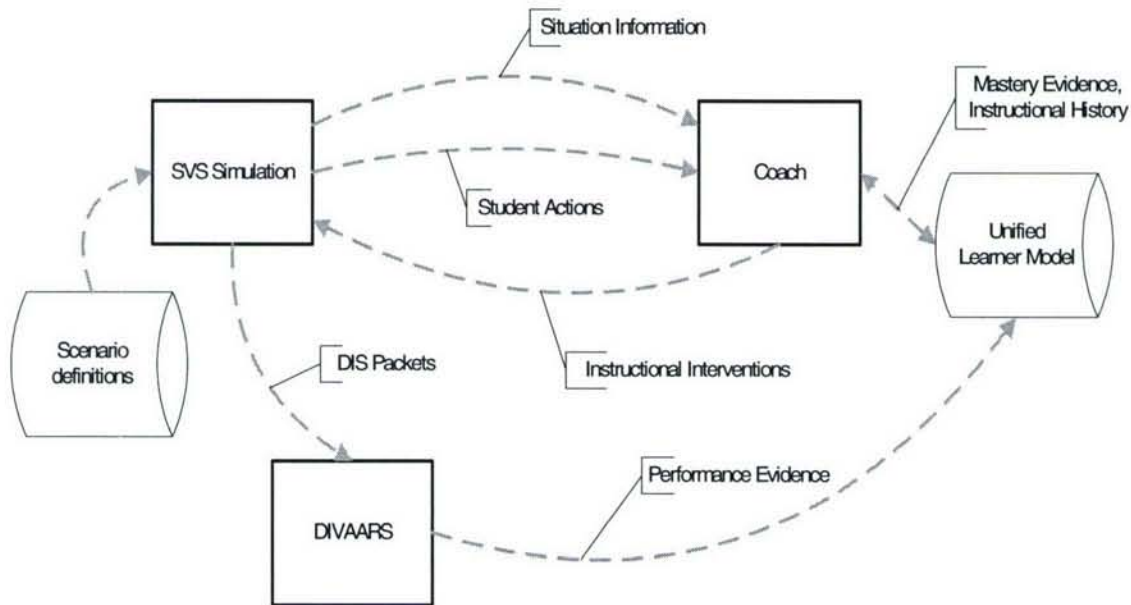


Figure 2. Major Component Relationships

The Soldier interacts with the SVS, undertaking activities in cooperation with other real and virtual entities. The real entities represent the additional members of the Soldier's unit. The virtual entities are CGF entities supported by SVS.

The SVS™ Dismounted Infantry (DI) Immersive simulation system is a first-person human-in-the-loop virtual simulation environment. The simulation generates the synthetic environment and other objects and entities and renders the resulting images onto a display screen. The Soldier interacts with the SVS, undertaking activities in cooperation with other real and virtual entities. The real entities represent the additional members of the Soldier's unit. The virtual entities are CGF entities supported by the SVS. The Soldier controls his movement through the environment by means of a joystick. The Soldier can see and be seen by other entities in the environment. He can also engage these entities with his weapon, and can be engaged by them.

The Soldier performance assessment and feedback component, known as the Coach, uses situation data and Soldier action information obtained from the simulation environment via a messaging protocol and its own internal knowledge base and heuristics to assess the situation and evaluate the Soldier's performance with respect to the situation. It attempts to answer the same question as a human Observer/Controller: "Given observed conditions, what is an appropriate response for the Soldier?"

As Soldier behaviors are assessed, the Coach's conclusions about their correctness are recorded in Sonalysts' Unified Learner Model (ULM) data store (see Appendix C) and forwarded to the Coach's internal Instructional Expert sub-component. The data stored in the ULM consist of attributed learning objective mastery evidence. In addition, a VOC data store records detailed performance evidence for each Soldier. The Instructional Expert uses instructionally sound selection mechanisms or triggering conditions to instigate various instructional strategies, such as providing real-time feedback during an exercise, all of which are recorded for potential use in the AAR. The AAR functionality exploits various data and events and their context as recorded by both DIVAARS and the Coach and is discussed in more detail in the VOC AAR Capabilities section of this report.

The Trainer Control Component (TCC) is responsible for configuring sessions and/or scenarios for instruction, managing Soldiers and their data, and configuring data for the AAR component. It is the primary manager of the central database that ties all the system components together. The functionality of the TCC can be divided into three modes of operation: Administrative, Instructional, and Review. The Administrative mode is responsible for creating, managing, and deleting users. As well as basic user management this module manages user data (i.e., AAR data, simulation play-back data, and Coach data). The functionality in this module will create, disable, and delete users. It will perform also the log-on, log-off validation of users. The Instructional mode is responsible for managing training scenarios and managing and configuring training sessions. The Review mode will facilitate the operations involved in selecting and activating a just completed session or a selected saved session for the AAR.

System Component Integration

The three major functional components, SVS simulation, Coach, and AAR are connected via formal interfaces. A closely coupled simulation-coach system results in data being scattered around inside the simulation processing, making it difficult to maintain as a separate entity. Furthermore, changes in exercise scenarios processed by the simulation can unexpectedly uncover brittleness in the encoded knowledge. Sonalysts has adopted a fairly sharp distinction between what kind of processing or knowledge belongs in the simulated environment and what belongs in the intelligent components. The simplest explanation of this approach is that the simulated environment exists to provide Soldiers with the ability to do whatever they need to do to accomplish the tasks for which the trainer is being built, but not to evaluate the correctness or incorrectness of those actions. Any assessment of the learner's activities must occur in the Coach and AAR components.

Consistent with this notion, the SVS-Coach interface is designed to tell the Coach two things:

- What should the Soldier be doing?
- What is the student doing?

These two types of information are supplied to the Coach by the simulation in the form of three types of messages: Expectation, Action and Outcome. Expectation messages provide information about the virtual world identified during the development of the cognitive model, as necessary to establish the correct expectations of Soldier behavior. An example of such information would be an OPFOR firing on a friendly unit. An Action message provides indications that a Soldier has done something, such as send a communications up the chain of command. Outcome messages, defined as messages that do not neatly fit the model of either an Action or an Expectation message, include messages that keep the Coach informed about the passage of time in the virtual world. The information provided by these messages can be summarized as follows:

- Each discrete action that a Soldier might take with any associated data,
- Every situation in which those actions are reasonably expected to be performed and the associated data.

From an implementation point of view, the interface between the SVS and the Coach is a TCP/IP-based messaging protocol created specifically for the VOC. The messages passed through this protocol include tactical situation data, Soldier action messages and real-time feedback (see Appendix D).

The interface between the SVS and the AAR uses a DIS protocol. The content of these messages comprises information about every significant entity event in the simulated environment. This amount of information is necessary to enable AAR support for a comprehensive replay capability. The AAR component utilizes also the ULM data store to support the analytical debrief, with the interface accomplished via an established ULM API.

VOC Automated Speech Recognition (ASR)

The purpose of the Automated Speech Recognition (ASR) component is to recognize utterances spoken by Soldiers during a training exercise. The ASR receives spoken utterances via a head-mounted microphone and converts them to a standardized message format, which is passed to the SVS simulation environment. The recognized spoken utterances are then converted into the formalized messaging protocol used by the simulation and Coach. Once the Coach has received the converted utterance, it assesses the Soldier's words.

The ASR makes use of a semi-formal grammar of limited scope. An important feature of the integration approach taken to add ASR to the VOC is that not only can the ASR grammar can be extended, but the mapping between the grammar and the formalized Coach-Simulation messaging protocol is data-driven. However, because the ASR does not interpret spoken words accurately, the VOC system provides a backup to the ASR engine, which is a menu driven communications mechanism from the SVS user interface. Table 1 provides an overview of the utterance types the ASR engine may recognize and provides one example utterance of each type (see Appendix E).

Table 1.

Examples of Verbal Messages Recognized by the ASR

	Message "Type"	Example Message
1.	Contact report	• Red 1, this is Red 11, Contact Northeast, Out
2.	Set report	• Red 1, this is Red 11, Set at CP4, Over
3.	SITREP	• Red 1, this is Red 11, have secured Objective 2, conducting consolidation, ACE report to follow, Over
4.	Room Cleared	• Red 1, this is Red 11, Room 1 clear, Over
5.	Move orders	• Red 11, this is Red 1, move to CP 1 now, Over
6.		• Red 11, this is Red 1, move to CP 2, report when set, Over
7.	Assault order	• Red 11, this is Red 1, execute assault, Over
8.	Enter Building (i.e., first room entry)	• Red 11, this is Red1, execute entry now, Over
9.	Wolf tail order	• Red 11, this is Red 1, mark all cleared rooms, Over
10.	Respond to orders from superior	• Red 1, this is Red 11, Roger, Over
11.	Order Evacuation of Wounded personnel	• Red 1, this is Red 11, have two friendly WIA, request MEDEVAC, Over
12.	Order medical treatment for wounded personnel	• Red 1, this is Red 11, request Medic at my location, Over
13.	Direct subordinates to send "ambiguous" personnel to superiors	• Red 11, this is Red 1, move all non-combatants to a secure location, Over
14.	Order subordinates to remove weapons/ordnance from building	• Red 11, this is Red 1, move all captured weapons and ammo to a secure location, Over

The ASR capability allows the Soldier a much more natural interface to the virtual world, because in the real world, menu systems are not used to converse among squad members. Additionally, because the ASR engine is only listening to voice traffic moving over the digital audio path supported by the SVS simulation environment, Soldiers can talk to each other in the virtual environment exercises even if they are not physically co-located. Lastly, because the VOC system includes a full AAR capability, the voice traffic is recorded for use during AAR sessions.

VOC Real-Time Coaching

Table 2 provides a summary of the Soldier behaviors for which real-time Coaching may be provided (see Appendix F).

Table 2.

Soldier Behavior for Which Real-Time Coaching May be Provided

Expectation Name	Expectation Description
Acknowledge Subordinate	Expects the superior to acknowledge the message sent by a subordinate.
Acknowledge Superior	Expects the subordinate to acknowledge a message sent by a superior.
Approach Building	Two flavors of this expectation exist depending on whether the Squad Leader or Team Leader receives an order to approach the building. Both versions expect the Soldier to acknowledge the order, order their subordinates to move and then actually move to position.
Contact Report (for visual enemy detection)	Expects the Soldier to issue a Contact Report to their superior.
Contact Report (receipt of report from subordinate)	Expects the Soldier receiving the Contact report to acknowledge it and forward to higher.
Enter Building	Expects the Soldier to acknowledge an order to enter the building, order his team into the building, and then to enter the building.
Provide Security for Civilian	Expects the Soldier to order a subordinate to secure the civilian and report the civilian's existence to higher.
Enter and clear room	Expects the Soldier to enter a room, thoroughly search it and report the room cleared to higher.
SITREP	Expects the Soldier to issue a SITREP to higher in response to a number of different situations (e.g., KIA, WIA)
Weapons/Ordnance Discovery	Expects the Soldier to report the discovery to higher.

VOC AAR Capabilities

The VOC AAR user interface represents enhancements to the current DIVAARS interface, which currently provides DVD-like replay of any recorded exercise and the ability to view the exercise from any angle and to jump in time to previously tagged events. The analytical AAR will add several features to these capabilities such as multiple performance views and an automatically guided AAR using DIVAARS. Data collected by the VOC Coach provide the basis for much of the new analytic AAR capabilities (see Appendix G). The features of the analytic AAR are discussed in the following paragraphs.

The VOC Coach keeps track of events from the simulation exercise. Certain events cause the Coach to expect certain actions from the Soldier. These expectations are visualized for each Soldier on a timeline. They are coded so that success or failure on a certain expectation is immediately evident. In a separate part of the view, simulation events, such as gunshots, are visualized. This allows real-world events and coach expectations to be visually correlated. Also, double-clicking on any expectation in the

view will cause DIVAARS to jump to that point in the simulation, so that the events surrounding that expectation can be replayed visually. The Expectation/Event View overlaps the main DIVAARS visualization view, and the current view is selected using notebook-style tabs, as shown in the Figure 4 below.

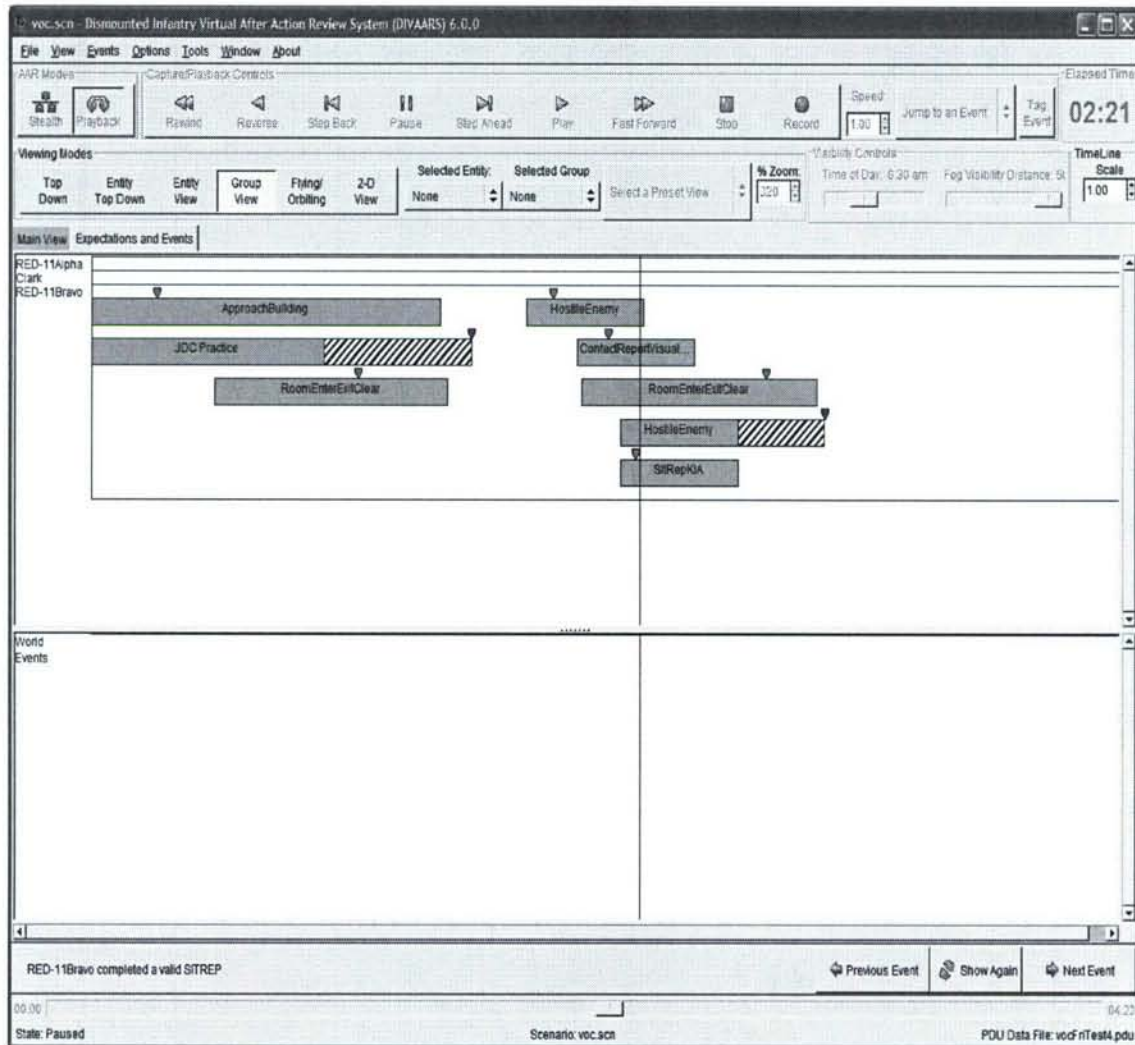


Figure 3. The VOC Expectations/Events View.

Expectation Details

There are several detailed views available for each expectation. The first is the Learning Objectives detail. This view shows the various Learning Objectives that are associated with the expectation. Learning Objectives are the basic concepts that the system is designed to teach. These Learning Objectives are associated with each of the procedures and steps that make up any given expectation. The Coach will score the Soldier's mastery of each Learning Objective as each expectation is completed. The expectation's Learning Objectives and mastery data are viewable from the Learning Objectives detail, as shown in Figure 5.

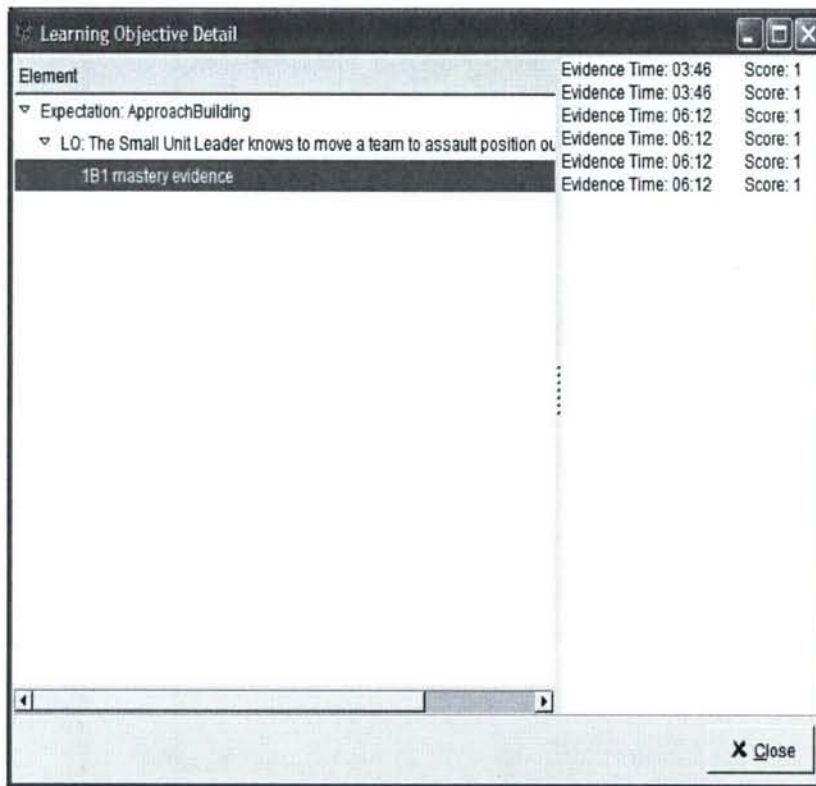


Figure 4: The Learning Objectives Detail View

The Second Detail View is the Expectation Elements Detail, which shows a visual representation with its steps and sub-procedures. The expectation's associated steps are shown in a timeline view, with the same performance color-coding and marking as the Expectation/Event View itself. The Expectation/Event View is shown in Figure 6.

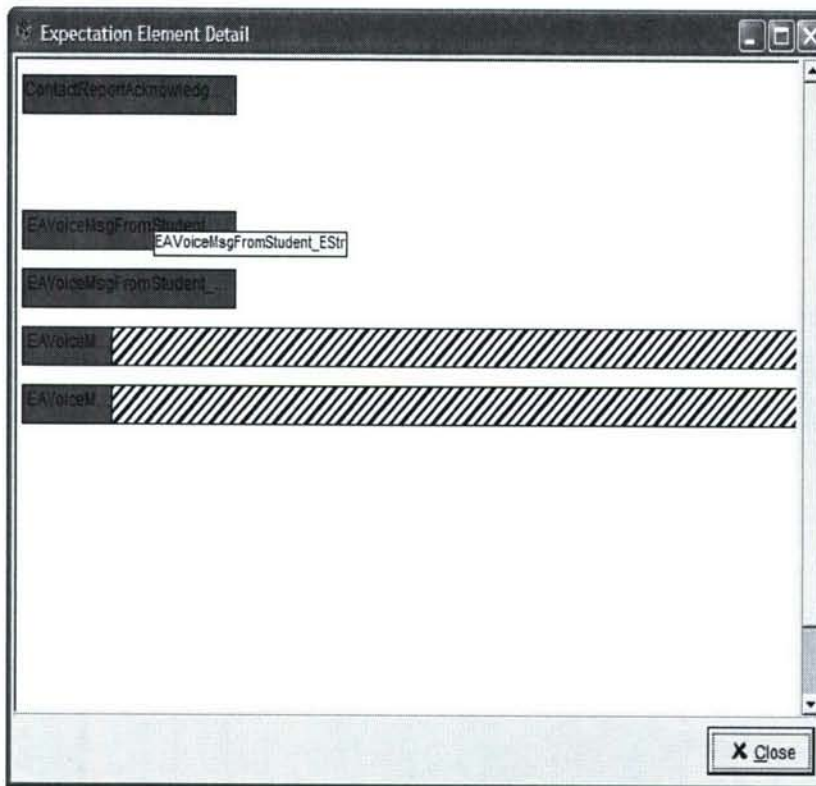


Figure 5: The Expectation Element Detail View

Finally, the Procedures/Actions Detail view breaks down the expectation into sub-procedures and actions, but uses a tree-style view similar to the Learning Objective Detail. The same expectation shown in Figure 6 is also shown in Figure 7, using the Procedures/Actions Detail view.

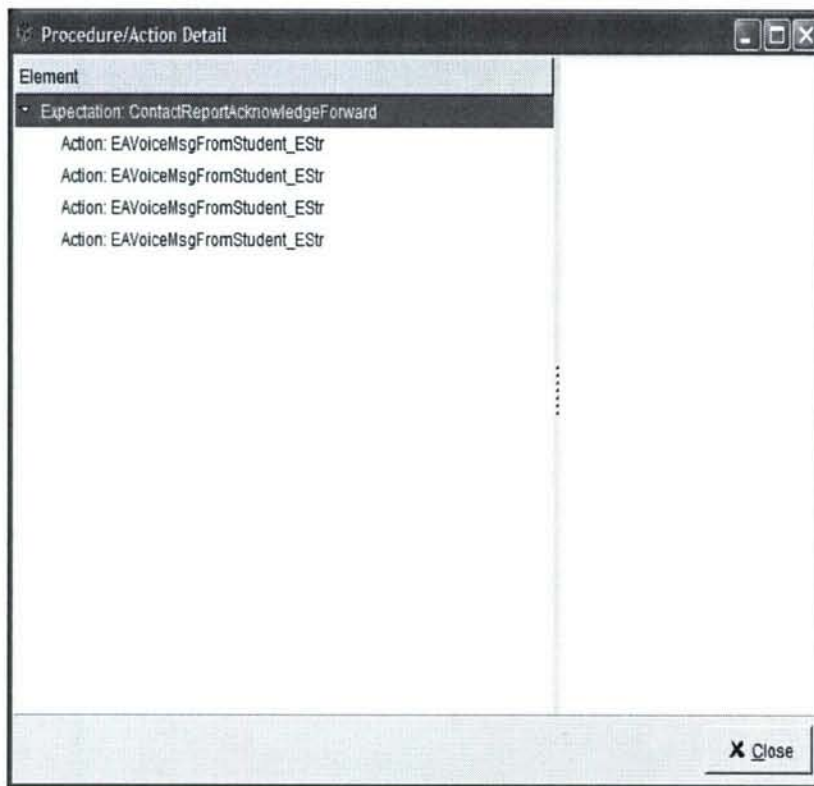


Figure 6: The Procedure/Action Detail View

Performance Graphs

In addition to the expectation timeline and detail views, DIVAARS can also capture the performance data and mastery endorsements generated by the Coach, and visualize these as graphs. The first performance graph is the High-level Performance graph, shown in Figure 8 below. This rendering shows a multi-line graph, where each line represents a high-level concept, such as communications, leadership, or movement techniques, as defined by the Coach's Learning Objectives. The line shows the number of positive endorsements by the Coach for each high-level Learning Objective divided by the total number of endorsements, arriving at an overall score between 0.0 and 1.0.

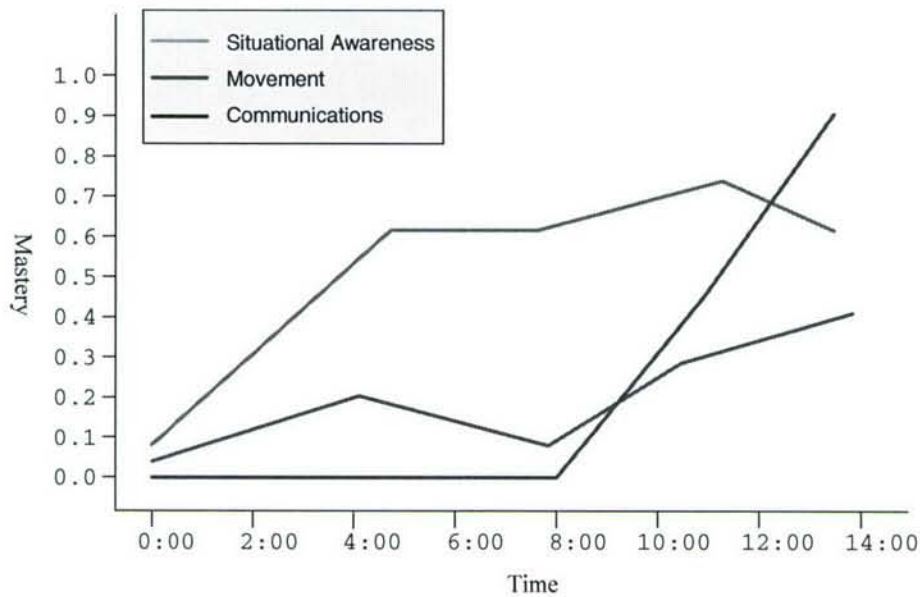


Figure 7: The VOC High-level Performance Graph

The second performance graph is the Event Timeline Performance graph, which shows an overall performance metric, along with significant events tagged on the timeline for easy identification. The metric in this case is the sum of the endorsements by the coach (both positive and negative) divided by the total number of endorsements. This metric shows whether the exercise was predominately positive or negative, and allows for significant shifts in performance to be easily seen. The Event Timeline Performance graph is shown in Figure 9.

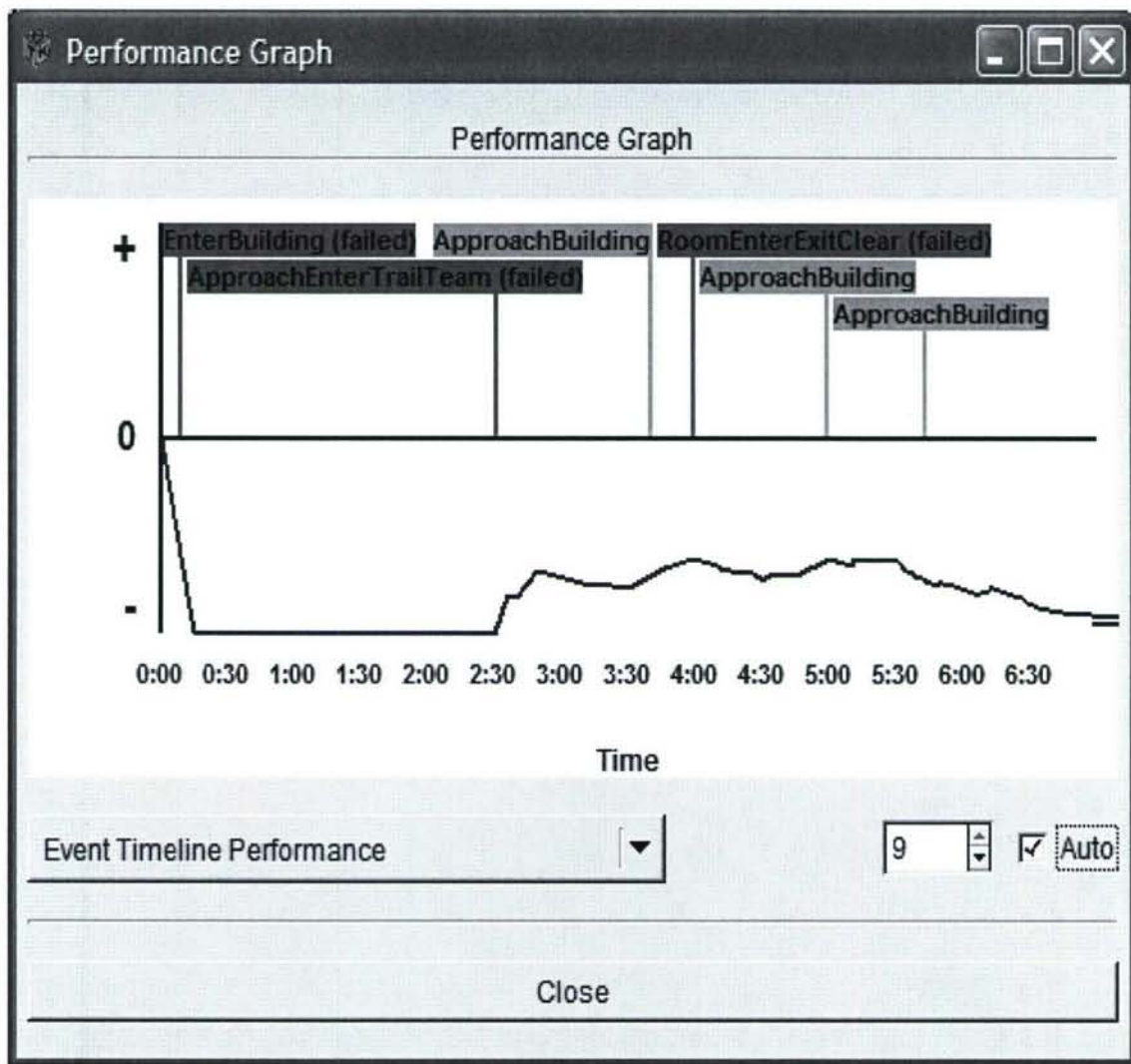
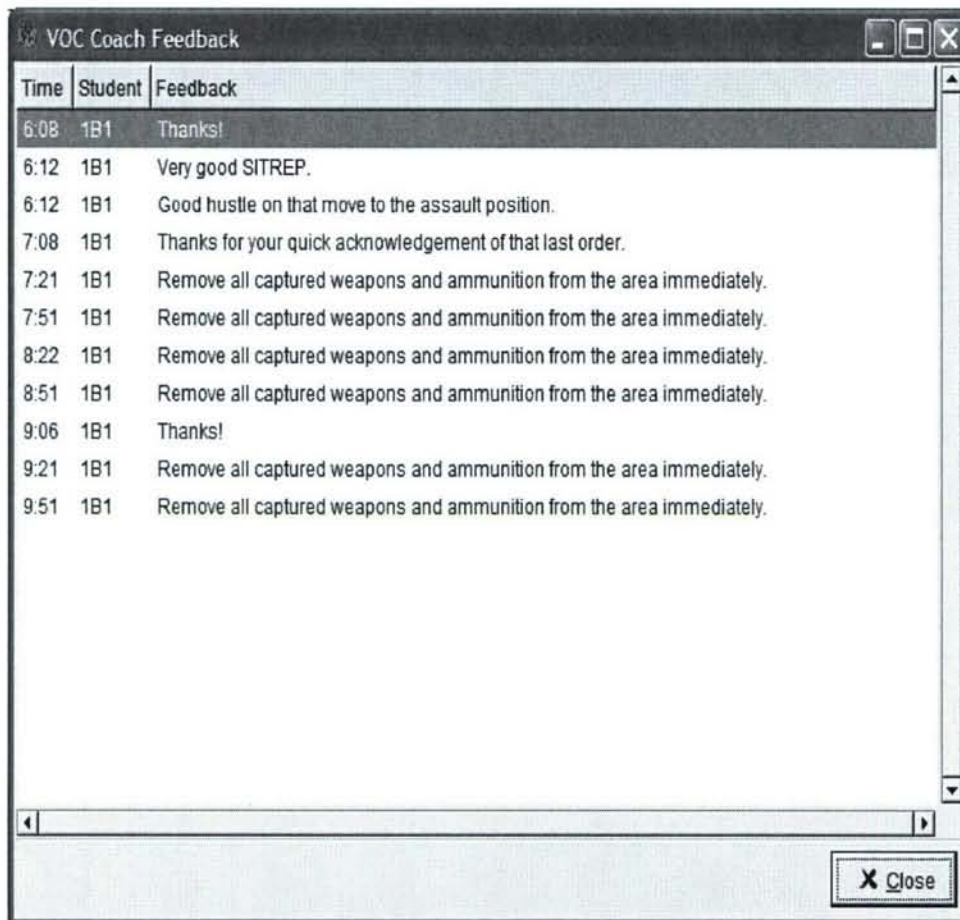


Figure 8: The Event Timeline Performance Graph

Coach Feedback

Feedback is generated by the Coach in real-time as the Soldiers progress through the exercise. This feedback is also captured and presented by DIVAARS. Additionally, feedback can be generated by the Coach for display only in the AAR session. The feedback can be shown by DIVAARS in two ways. First, there is a chronological listing of the feedback, as shown in Figure 10. The feedback shown in this figure is indicative of some good behaviors and one Soldier behavior that was performed very late, resulting in several negative feedback messages, with one message given to the Soldier every thirty seconds.



The screenshot shows a window titled "VOC Coach Feedback" with a table of feedback messages. The table has three columns: Time, Student, and Feedback. The messages are listed chronologically from 6:08 to 9:51. Most messages are from student 1B1 and consist of either "Thanks!" or "Remove all captured weapons and ammunition from the area immediately." There is one message at 6:12 from 1B1 that says "Very good SITREP." and another at 6:12 from 1B1 that says "Good hustle on that move to the assault position." The window has a standard Windows-style title bar with minimize, maximize, and close buttons. At the bottom right, there is a button labeled "X Close".

Time	Student	Feedback
6:08	1B1	Thanks!
6:12	1B1	Very good SITREP.
6:12	1B1	Good hustle on that move to the assault position.
7:08	1B1	Thanks for your quick acknowledgement of that last order.
7:21	1B1	Remove all captured weapons and ammunition from the area immediately.
7:51	1B1	Remove all captured weapons and ammunition from the area immediately.
8:22	1B1	Remove all captured weapons and ammunition from the area immediately.
8:51	1B1	Remove all captured weapons and ammunition from the area immediately.
9:06	1B1	Thanks!
9:21	1B1	Remove all captured weapons and ammunition from the area immediately.
9:51	1B1	Remove all captured weapons and ammunition from the area immediately.

Figure 9: The VOC Feedback Listing

Feedback messages can also be shown anchored to the main visual playback. During playback, an icon appears next to a Soldier's avatar whenever that student received feedback from the coach. Clicking on this icon will pause the playback, and present a pop-up window with the feedback text. This view is shown in Figure 11.

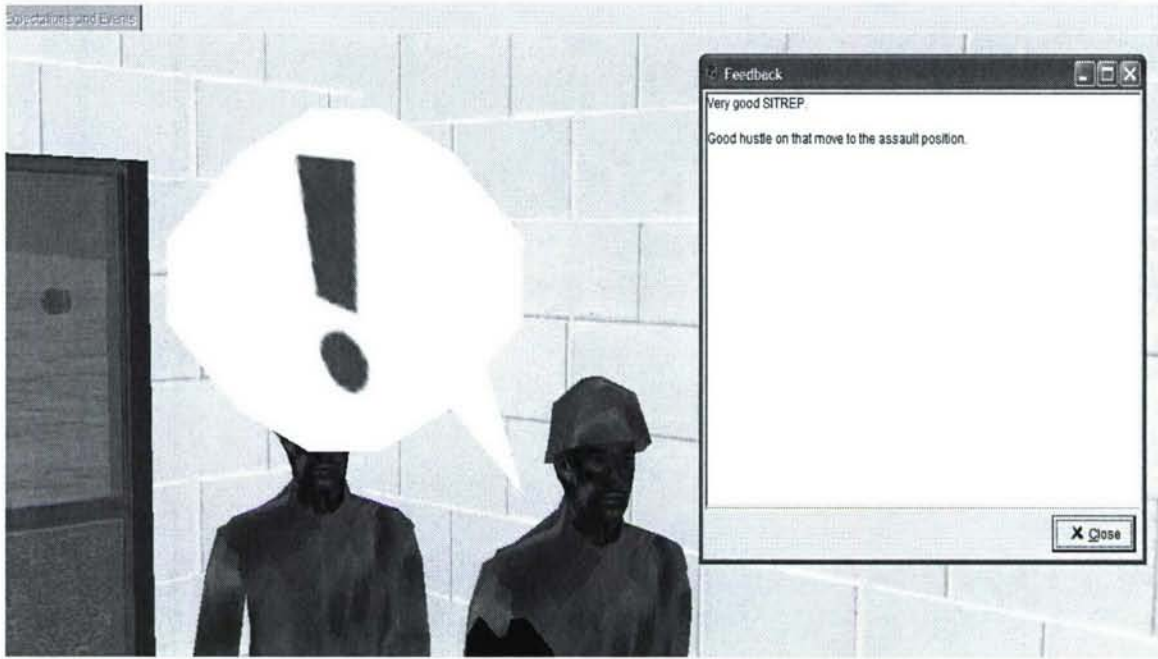


Figure 10: Pop-up feedback view during normal playback.

Guided AAR

The VOC supports an AAR session guided by the data collected from the Coach. Expectations and significant events are presented in order, allowing the Soldier to jump from one event to the next without the need to view them serially. Additionally, the events to be presented can be filtered based on unit (e.g., entire squad, fire team A, or fire team B), detail (e.g., default or fine), and area of interest (e.g., tactical execution, mission objectives, and rules of engagement).

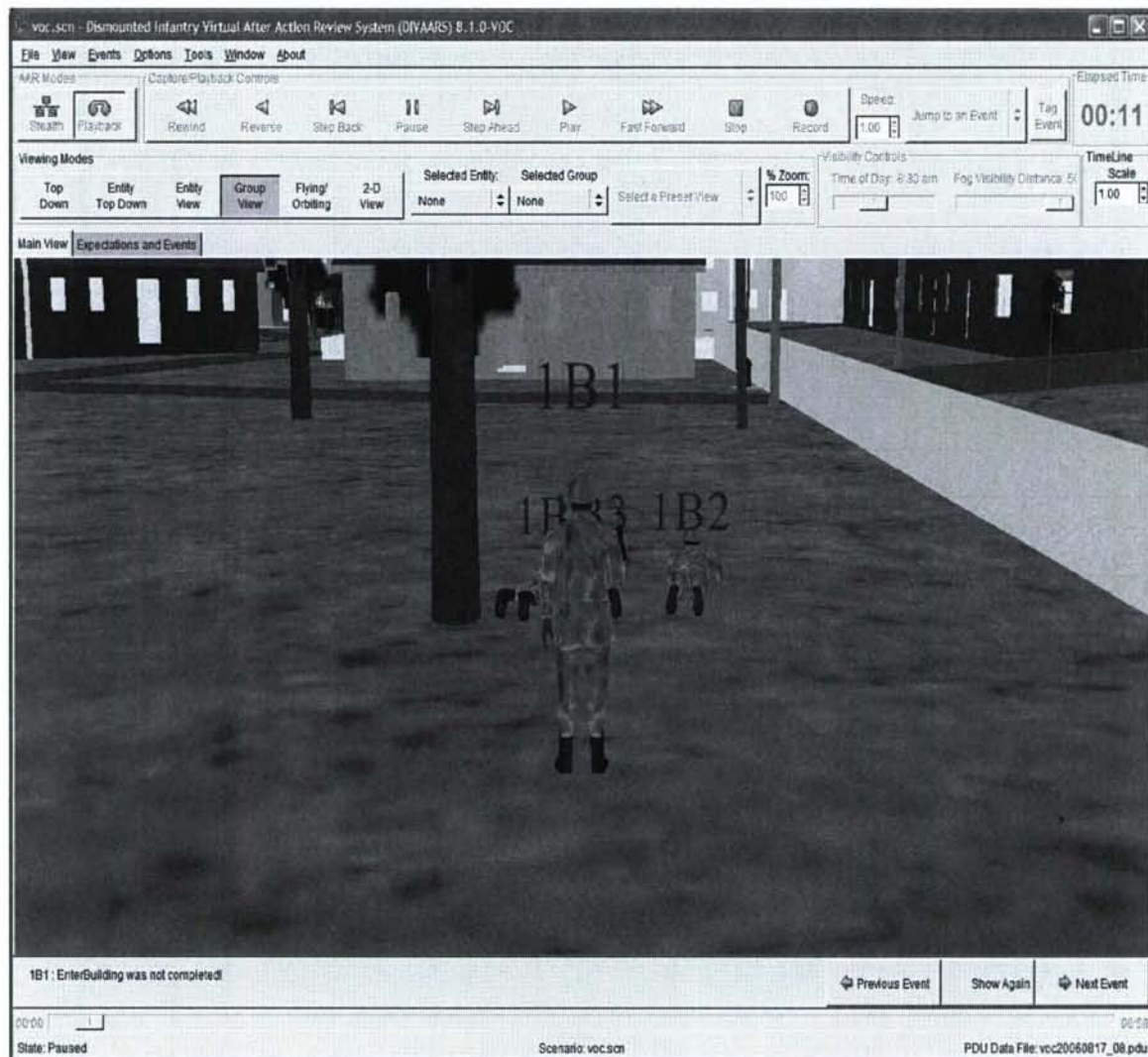


Figure 11: A Guided AAR session in progress, showing the guided AAR interface at the bottom of the main view.

DISCUSSION

This section will provide a discussion of the lessons learned during the development of the VOC as well as a discussion of some technical issues that should be investigated should further development of the VOC occur.

Room Clearing

Providing the Coach with the concept of rooms in a building was non-trivial. There was a goal to avoid re-creating the 3D world and various movement and state algorithms inside the Coach because this would entail duplicating significant aspects of the simulated environment which would be a waste of effort and run-time computing

resources. In order to avoid this redundancy, a smart simulation instrumentation enabled the simulation to exploit the messaging protocol and to communicate to the Coach efficiently about the simulated environment and the contents therein. Essentially, every object in the virtual world is placed in some room with an identifier attached to it, including the space that represents objects outside the building.

At scenario initialization the Coach is told about all the objects in the simulated world and builds a list of rooms from those messages. The simulation also provides the Coach with messages any time an object enters or leaves a room, allowing the Coach to track the movement of the Soldiers and to know what objects they should see in any room they enter. The simulation also tells the Coach when an object in the virtual world is seen by a Soldier. This technique allows the Coach to determine that a Soldier has entered a room, properly searched it, and taken the actions necessary for any objects of interest (e.g., weapons) that are in the room.

Determining that a Soldier has thoroughly searched a room has been handled by exploiting the technique described above for objects and rooms. Each room in the building to be searched includes a number of invisible objects, about which the Coach knows. Every object that passes into the field of view of the Soldier generates an “Object Seen” message to the Coach, allowing the Coach to know when every object in a room has been seen (or not). The coach can detect when a Soldier has failed to do a complete visual sweep of a room. The coach can wait a reasonable amount of time before reacting to an incomplete search. Or, it can recognize when a Soldier has either left the room or reported the room has been cleared when there are still dangerous objects in the room that the Soldier did not detect. Additionally, these objects have useful descriptions associated with them that are used in feedback messages. The Soldier can be told by the coach that they have not looked in a specific place a room.

Scope Management Decisions

In developing the VOC as a Research and Development effort on a fixed budget, decisions were made to restrict the level of effort necessary to produce the prototype without impacting the instructional usefulness of the VOC. The primary goal of this effort was to develop sufficient functionality in the VOC to allow for an assessment of the instructional effectiveness of such a training system. A secondary goal was to explore the various technological aspects of embedding an automated Coach/AAR in a first-person simulation in order to acquire knowledge and insight regarding what it would entail to build a production system. Managing the development in this manner required that each time a simplifying assumption was made to control the scope of the prototype, it was thoroughly examined to ensure it did not inadvertently gloss over a hard technical problem. This meant that each time a simplifying assumption appeared reasonable for reducing the level of effort, the consensus was that the “non-simple” solution was in fact possible and feasible. Several of these strategic decisions are discussed in the following paragraphs.

A fundamental simplification was to use only one building for all the scenarios. This enabled fixing the location where fire teams are supposed to go when approaching the building in preparation for building entry. Similarly, the subsequent staging points within the building can also be fixed. This meant that the simulation did not have to provide the Coach with staging point data as part of a messaging protocol, but rather it could be defined as part of the scenario definition data. Additionally, there are simulation-specific building definition activities related to identifying room names and descriptors as well as defining virtual world zones that only had to be done once if there were only one building. All the activities that were left undone as a result of this effort have been fully explored and do not represent a technical risk for a production VOC.

A second simplifying decision was to fix any enemy force positions inside a building during any particular exercise. This allowed for a more simplified situation assessment capability in the Coach processing, primarily in tracking objects seen by a Soldier in the exercise. In order for the Coach to create reasonable expectations of a Soldier based on what they have seen as they move through the virtual world, the simulation sends visual cue messages to the Coach. These messages are based on the on-screen rendering of graphical objects in the human Soldier's field of view, including an OPFOR, if the Soldier encounters one in the building. Once the simulation tells the Coach that a Soldier has seen an OPFOR in a particular room, then the Coach records this information and creates an expectation that the Soldier will issue a Contact Report. By fixing the OPFOR's location, the Coach does not have to deal with the possible rapid motion of the OPFOR through or out of the building where they might encounter other friendly forces. Thus, the Coach can safely assume that the Soldier who first saw the OPFOR is supposed to report it, and the Coach does not need to algorithmically track the OPFOR to see which other Soldiers should take action. Because the messaging protocol does support the real-time updating of moveable objects in the world, and because the Coach does manage objects dynamically, this simplification does not cause the Coach to be unreasonably brittle about its understanding of the virtual world.

A third simplifying decision involves the general notion of visual cues a Soldier might see in the virtual world. While it is a non-trivial task to determine what a Soldier might or might not have seen in an arbitrarily complex virtual environment, the scenarios were designed to minimize ambiguous situations by including mostly large, stationary visual objects. However, the messaging protocol includes several pieces of data that would support more realistic "did the soldier see it" algorithms, such as the amount of time the object was rendered on the user interface. Additionally, the internal Coach processing has been architected so that it is quite straightforward to insert a complex algorithm that attempts to determine if an incoming message warrants creating an expectation that the Soldier deal with it appropriately. For this effort the decisions were based on a desktop virtual environment. A fully immersive environment would bring with it a new set of challenges related to head and eye tracking which have not been addressed in this effort.

A fourth simplifying decision relates to trainee data. While the Trainer Control Component, discussed above, provides sufficient functionality to configure and run

training exercises, a much more robust and full-featured application will be necessary for a production VOC. Several important issues, such as robust data custody, security, and management (e.g., deletion of unneeded data) have not been adequately addressed. However, the data schema developed for the prototype provides the necessary data relationships to support a production quality data management scheme, including the capability to use different database systems (e.g., Microsoft Access, Microsoft SQL Server).

Automated Speech Recognition

In the early stages of development, three possible speech engines were identified. One was the IBM ViaVoice system. ViaVoice has a reputation for high accuracy and reliability, and has worked well with previous projects. Unfortunately, ViaVoice is commercial software, and would require a per-seat license when deployed. As a result, ViaVoice was abandoned early in development. Next, the SPHINX engine from Carnegie Mellon University was examined. Sphinx is Java-based software, providing cross-platform functionality, and it is also free, open-source software. Software developers at IST had experience using SPHINX, so it was initially selected to be the VOC speech engine. After implementing a small portion of the VOC grammar using SPHINX, it was discovered that it consumed a large amount of resources (around 650 MB) for even the limited VOC grammar. Because the goal was to run the ASR system on the same computer as the SVS simulator, the decision was made to abandon SPHINX.

The final version of the ASR system was implemented using Microsoft's Speech API (SAPI). This API uses Microsoft's Component Object Model (COM). The ASR software was written using C++. However, because the VOC uses COM, cross-platform capability has been sacrificed. This did not pose a problem for the VOC project because the target platform was Windows. Microsoft SAPI is commercial software, but is freely distributed by Microsoft, which means that there is no development or per-seat licensing cost (beyond the normal cost for Windows XP itself). In contrast to SPHINX, the memory footprint for the ASR system running under the Microsoft SAPI is only 16-25 MB. The CPU load is also minimal, enabling the SVS system to run with the ASR software on the same machine without exhausting computational resources on the target hardware.

Future Efforts for a Production VOC

There are several aspects of the VOC which we encountered that suggest worthwhile further efforts. The next few paragraphs discuss some of these areas for further investigation and what was learned about how to proceed in addressing them.

Friendly Forces Firing

Dealing with the issues surrounding friendly fire has been largely deferred. The Coach handles the fairly simple situation of a Soldier entering a room containing a

civilian and recognizing that shooting is incorrect behavior. The VOC architecture allows for significantly more sophisticated processing to be added to assessing friendly forces firing their weapons. One example explored earlier was the recognition that friendly forces fired too many rounds in response to some stimulus. The messaging protocol includes provisions for telling the Coach which friendly unit fired, which type of weapon was fired, how many rounds were fired, and the trajectory of the rounds. The Coach could use this information, in combination with its knowledge of where and how many enemy forces have been identified to perform an assessment of the friendly forces behavior.

There are several interesting challenges that arise in considering whether a friendly unit should fire. Consider the following series of notional rules, all of which can be in effect at the same time, with differing levels of importance, depending on the situation. They all help to determine if the fire team should fire:

- If the fire team is taking fire and knows the location of the enemy, then return fire.
- If the fire team sees the enemy and the ROE permits it, then the fire team should fire at the enemy.
- If the fire team has recently seen an enemy and the element of surprise has already been lost and the ROE allows it, then the fire team should fire at the last known location of the enemy.
- If the enemy does not know the fire team's position and stealth is important and the enemy is adequately suppressed, then do not fire.
- If in hostile environment and the ROE is non-restrictive and the enemy location is known with confidence and the fire team has been fired at, then fire at the last known enemy location.

Notice that in these rules the "If" clause is the situation condition and the "Then" clause is the expected action that relates to the condition. Thus, the information that is needed out of the simulation environment is whatever will inform the coach that the "If" condition has occurred. In the list of rules above, the following "If" conditions must be identified:

- Fire team is being fired at
- The fire team has been fired at
- Fire team sees an enemy
- Fire team has recently seen an enemy
- ROE in effect
- The enemy does not know the fire team's position
- The element of surprise has been lost
- Stealth is important
- The enemy is suppressed
- The enemy's location is known

The first item, “Fire team is being fired at” requires that we resolve what being “fired at” means. There are two aspects to this information. The simulation environment has knowledge of what the enemy is doing because it is under the control of the simulation. However, in most cases, the simulation should not inform the Coach of ground truth unless the Soldiers can also perceive ground truth through their interface with the simulation environment. Thus, the Coach should only be told what the Soldiers can know about the situation. In this case, the fire team will likely hear the sound of the gunfire and, if the rounds are being fired in their direction, will see some indications of where the rounds are hitting. They might also see muzzle flash or smoke, if they were looking in the right direction when the shots were fired and if the enemy’s position made those visual indications possible. This suggests that the Coach should be sent information regarding the following items:

- The fire team should have heard gunfire
- The fire team should have heard round impact audio cues
- The visual cues of the enemy’s fires were visible
- Round impact visual cues were visible

Assessing and coaching pertaining to taking cover when receiving incoming fire has been largely deferred. However, we carefully considered what it would mean to assess whether a friendly unit took reasonable action in response to taking hostile fire. One aspect is that the messaging protocol includes a design for a message that would tell the Coach about cover objects. The Coach would need to know several attributes about potential objects if it is to assess their suitability for use as cover in the face of hostile fire. These attributes, included in the design of the messaging protocol, but not yet implemented, are:

- The location of the object
- What type of round it will stop
- The size of the object (computed dynamically using the relative positions of the friendly unit and the probable source of the incoming fire)
- A descriptive name for the object

Taking Cover

Assessing the Soldier’s selection of a cover object assumes that the direction of the incoming fire is known to some degree. However, this is not always true. The Coach must first assess the situation and determine whether the Soldier could know enough about the location of the incoming fire to reasonably select a cover position or object. Also, the Coach could determine that the Soldier ran past a suitable cover object and selected another suitable cover object, but one that was much farther from his initial position than necessary.

Feedback Delivery

The issue of the intrusiveness of real-time feedback has not been explored, primarily because the formal evaluation of the VOC has not yet occurred. All feedback is currently delivered via a text display in the upper right hand corner of the simulation screen. The VOC has provisions to designate specific feedback messages to be delivered via text display or using a text-to-speech engine, but no text-to-speech system has been integrated with the processing of feedback messages in the simulation environment. Another aspect of feedback delivery that warrants more effort is to develop a situational sensitivity capability so unnecessary feedback is not delivered during periods of high Soldier stress or workload.

Rules of Engagement

One very significant area of investigation is incorporating different rules of engagement into the VOC. This is especially useful in the present environment where urban warfare in general and building clearing operations in particular are experiencing nearly constant change in applied tactics, techniques and procedures. The Coach's assessment of Soldier actions is heavily driven by a text-based language describing the expected behaviors for any given situation, about which the Coach already knows. This allows for scenario-by-scenario changes in what the Coach expects of a Soldier. However, there is plenty of room for exploration in how much more capability the Coach would need to be able to respond to changing tactics, techniques, and procedures.

Acronyms

AAR	After Action Review
ARI	Army research Institute
AIS	Advanced Interactive Systems
CGF	Computer Generated Forces
COM	Component Object Model
CTA	Cognitive Task Analysis
DAR	Decision Analysis and Resolution
DDE	Dynamic Data Exchange
DIS	Distribute interactive Simulation
FM	Frequency Modulation
IST	Institute for Simulation and Training
LO	Learning Objective
N/C	Not Coachable
POA&M	Plan of Action and Milestones
SAM	Supplier Agreement Management
STTR	Small Business Technology Transfer
SVS	Name of AIS dismounted infantry simulation, not an acronym
UCF	University of central Florida
VOC	Virtual Observer/Controller

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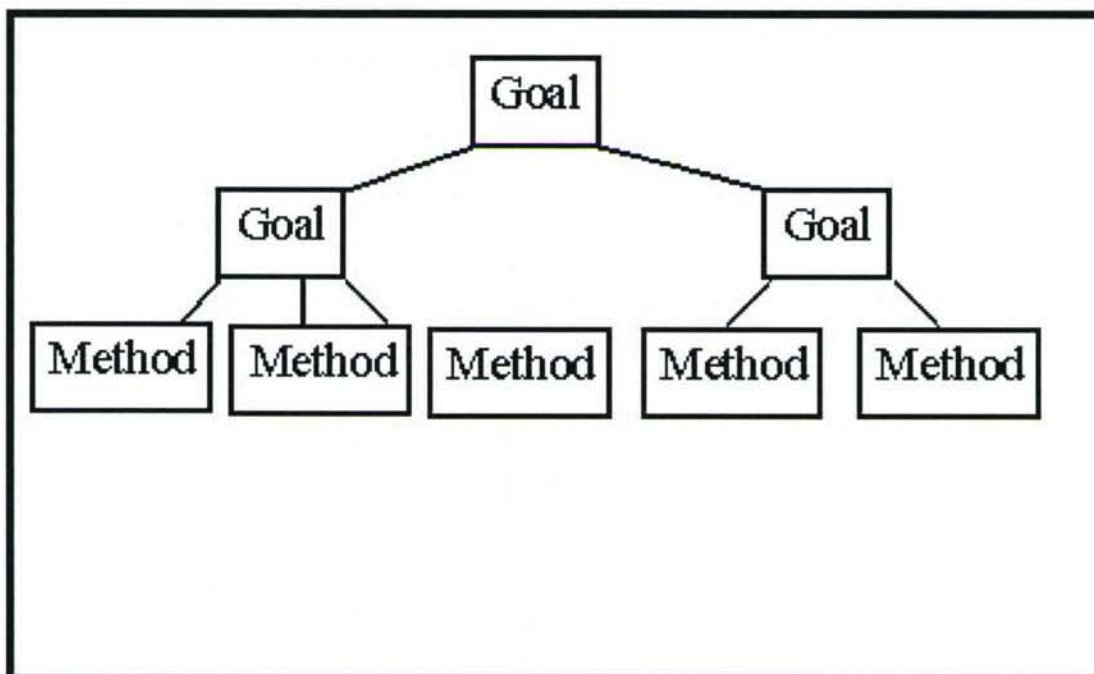
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APPENDIX A

Cognitive Model Contents

There are two cognitive models developed for the VOC; one for the Squad Leader and one for the Team Leader. These models capture the tasks each of the unit leaders must accomplish in the context of the scenarios envisioned for the VOC. The tasks are arranged in a hierarchical fashion, as goals and methods, and this organization can be depicted as in the figure below.



The tree structure results from the explicit intention of the CTA to decompose the subject matter. Thus, some or all methods that are under the same goal are required to complete their parent goal. Not all methods are required if there are equivalent or synonymous methods. A specific example from the Squad Leader cognitive model illustrates this relationship.

- 1.1 The Squad Leader can approach a building to be cleared.
 - 1.1.1 The Squad Leader knows to move a team to assault position outside the building.
 - 1.1.2 The Squad Leader knows the proper use of cover and concealment.
 - 1.1.2.1 The Squad Leader uses smoke to conceal the move when appropriate.

This cognitive model fragment suggests that for a Squad Leader to properly approach a building they must be able to move a team to the assault position AND know to properly use cover and concealment.

The next step in the process is to use the goal/method graph to infer learning objectives. The learning objectives may map directly to goals and tasks, or a single learning objective may map to several identical methods. In developing the cognitive model and the learning objectives that derive from them, there is a process of developing a description of the correct and incorrect behaviors for each method. The correct behaviors are called “Targets” and incorrect behaviors are called “Bugs.” Bugs are customary or predictable errors that students might make during their performance and the ability to detect these Bugs is built into the Coach component’s knowledge base.

A significant implication of cognitive model development and contents is the fact that the requirements for the Coach component are derived directly from the cognitive model contents. Specifically, the Target and Bug descriptions are effectively considered “shall” statements. Considering the excerpt from the cognitive model cited above, goal 1.1.1 discusses moving an assault team. The description for the Target and one Bug for that item, are as follows:

- Target Description: Squad Leader gives the order to the Squad leader in the proper way, after Squad A signals it is ready.
- BugA Description: Squad Leader does not order Squad to assault position within the expected period of performance.

The following table contains the cognitive model developed for the Dismounted Infantry Squad Leader engaged in a platoon-lead building clearing operation. The Team leader cognitive model is presented in the table below. The first column is a hierarchical identifier used during the development of the models to manage the hierarchical relationships. The second column labeled “LO” or “Learning Objective,” contains a description of the desired behavior derived directly from the Goal or Method from which the learning objective was derived. The next column “Coaching Notes” provides a brief description of what the coaching goals are. The message required for the Coach to be able to assess the Targets and Bugs is indicated notionally in the next column “Supporting Sim Message.” The Targets and Bugs identified for each of these learning objectives are presented in the remaining columns. The specific “Bug A/B/C” nomenclature is arbitrary and is used for mapping the specific incorrect behavior to the Coach software responsible for assessing the behavior.

LO ID	LO Description	Coaching Notes	Supporting Sim Message	Target Description	BugA Description	BugB Description	BugC Description
1	The Small Unit Leader can successfully execute a tactical operation.	N/C					
1.1	The Small Unit Leader properly informs superiors during operations.	N/C					
1.1.1	The Small Unit Leader knows when to report to superiors.	N/C					

LO ID	LO Description	Coaching Notes	Supporting Sim Message	Target Description	BugA Description	BugB Description	BugC Description
1.1.1.1	The Small Unit Leader knows when to make a Contact report.	Small Unit Leader does or does not make a prompt Contact Report to Platoon Leader upon taking fire or making other contact with the enemy.	E: Sound Cue or Visual Cue A: Message Sent	The Small Unit Leader either attempts to send or does send a Contact Report to the Platoon Leader within the acceptable period of performance.	The Small Unit Leader does not report to the Platoon leader within the acceptable period of performance.	The Small Unit Leader sends the wrong report type.	The Small Unit Leader sends a Contact Report when there was no reason to.
1.1.1.2	The Small Unit Leader knows when to make a Set report.	Small Unit Leader does or does not report to the Platoon Leader when his/her unit is in position.	E: Unit Arrival A: Message Sent	The Small Unit Leader either attempts to send or does send a Set Report to the Platoon Leader within the acceptable period of performance.	The Small Unit Leader does not report to the Platoon leader within the acceptable period of performance.	The Small Unit Leader sends the wrong report type.	The Small Unit Leader sends a Set Report when there was no reason to.

LO ID	LO Description	Coaching Notes	Supporting Sim Message	Target Description	BugA Description	BugB Description	BugC Description
1.1.1.3	The Small Unit Leader knows to make a SITREP report when a room is cleared.	Small Unit Leader does or does not provide a Room Cleared report to Platoon Leader when it is appropriate.	E: Object Visibility A: Message Sent	The Small Unit Leader either attempts to send or does send a SITREP Report to the Platoon Leader within the acceptable period of performance.	The Small Unit Leader does not report to the Platoon leader within the acceptable period of performance.	The Small Unit Leader sends the wrong report type.	The Small Unit Leader sends a SITREP Report when there was no reason to.
1.1.2	The Small Unit Leader knows how to report to superiors.	N/C					
1.1.2.1	The Small Unit Leader knows how to properly make a Contact Report to superiors.	The Small Unit Leader does or does not make a Contact Report to the Platoon Leader using correct phraseology, report type and content.	A: Message Sent	The Small Unit Leader makes a properly constructed Contact Report with the appropriate and correct information within the acceptable period of performance.	The Small Unit Leader's report contains inaccurate information about the enemy contact.	The Small Unit Leader sends the report to the wrong person.	

LO ID	LO Description	Coaching Notes	Supporting Sim Message	Target Description	BugA Description	BugB Description	BugC Description
1.1.2.2	The Small Unit Leader knows how to properly make a Set Report to superiors.	The Small Unit Leader does or does not make a Set Report to the Platoon Leader using correct phraseology, report type and content.	A: Message Sent	The Small Unit Leader makes a properly constructed Set Report with the appropriate and correct information within the acceptable period of performance.	The Small Unit Leader's report contains inaccurate information about the units location.	The Small Unit Leader sends the report to the wrong person.	
1.1.2.3	The Small Unit Leader knows how to properly make a SITREP to superiors.	The Small Unit Leader does or does not make a Room Cleared Report to the Platoon Leader using correct phraseology, report type and content.	A: Message Sent	The Small Unit Leader makes a properly constructed SITREP with the appropriate and correct information within the acceptable period of performance.	The Small Unit Leader's report contains inaccurate information about the room clearing.	The Small Unit Leader sends the report to the wrong person.	
1.2	The Small Unit Leader can lead subordinates.	N/C					

LO ID	LO Description	Coaching Notes	Supporting Sim Message	Target Description	BugA Description	BugB Description	BugC Description
1.2.1	The Small Unit Leader knows when to provide orders to subordinates.	The Small Unit Leader does or does not provide orders to subordinates when appropriate.		The Small Unit Leader gives appropriate orders to his/her subordinates within the acceptable period of performance.	The Small Unit Leader fails to give orders to his/her subordinates within the acceptable period of performance.		
1.2.2	The Small Unit Leader knows how to give orders to subordinates.	The Small Unit Leader does or does not use the appropriate communication technique and report type and content for the tactical situation.		The Small Unit Leader uses the correct communication mechanism when issuing orders to the subordinate.	The Small Unit Leader gives no orders within the acceptable period of performance.	The Small Unit Leader uses an inappropriate communications technique.	
1.2.3	The Small Unit Leader can respond promptly and accurately to orders.	N/C					
1.2.3.1	The Small Unit Leader knows to acknowledge to orders.	The Small Unit Leader does or does not acknowledge an order from a superior.	E: Incoming Message A: Message Sent	The Small Unit Leader appropriately acknowledges an order within the acceptable period of performance upon receiving an order.	The Small Unit Leader does not acknowledge an order within the acceptable period of performance.	The Small Unit Leader acknowledges incorrect phraseology.	The Small Unit Leader acknowledges an order to the wrong person.

LO ID	LO Description	Coaching Notes	Supporting Sim Message	Target Description	BugA Description	BugB Description	BugC Description
1.2.3.2	The Small Unit Leader knows when to respond to orders.	The Small Unit Leader does or does not fulfill an order from a superior.	E: Incoming Message A: Message Sent	The Small Unit Leader responds or attempts to respond to an order within the acceptable period of performance upon receiving an order.	The Small Unit Leader does not respond to an order within the acceptable period of performance.		
1.2.3.3	The Small Unit Leader knows how to respond to orders.	The Small Unit Leader does or does not correctly fulfill the order.	E: Incoming Message A: Message Sent	The Small Unit Leader takes the ordered action within the expected period of performance.	The Small Unit Leader responds incorrectly.		
1.2.4	The Small Unit Leader can use correct movement techniques.	N/C					
1.2.4.1	The Small Unit Leader knows how to select movement techniques.	The Small Unit Leader does or does not which movement technique should be used in a particular situation.	E: Scenario Initialization Data A: Message Sent	The Small Unit Leader selects the correct movement technique.	The Small Unit Leader selects the wrong movement technique.		

LO ID	LO Description	Coaching Notes	Supporting Sim Message	Target Description	BugA Description	BugB Description	BugC Description
1.2.4.2	The Small Unit Leader knows how to employ movement techniques.	The Small Unit Leader does not correctly execute the correct movement technique.	A: Message Sent	The Small Unit Leader correctly executes the movement technique within the expected period of performance.	The Small Unit Leader does not execute the move within the expected period of performance.		
1.3	Can respond to enemy fire.	N/C					
1.3.1	The Small Unit Leader takes immediate cover upon taking fire.	The Small Unit Leader does or does not move to the closest suitable cover.	E: Sound Cue or Visual Cue A: Unit Movement	The Small Unit Leader moves to the nearest suitable cover within the expected period of performance.	The Small Unit Leader does not move to take cover within the expected period of performance.	The Small Unit Leader moves to a covered location too far away.	The Squad moves to a position that provides poor cover or no cover.
1.3.2	The Small Unit Leader knows to try and locate the enemy.	The Small Unit Leader does or does not attempt to locate the enemy.	E: Sound Cue or Visual Cue O: Friendly to Enemy Visibility A: Object Visibility	The Small Unit Leader takes appropriate action to try and determine the location and strength of enemy unit initiating fire within the expected period of performance.	The Small Unit Leader does not take any action within the expected period of performance.	The Small Unit Leader makes an insufficient effort to locate the enemy.	

LO ID	LO Description	Coaching Notes	Supporting Sim Message	Target Description	BugA Description	BugB Description	BugC Description
1.3.3	The Small Unit Leader knows when to request heavy weapons support.	The Small Unit Leader does or does not request the Platoon Leader provide heavy weapons when it is tactically appropriate.	E: Sound Cue or Visual Cue A: Message Sent	The Small Unit Leader requests heavy weapons squad within the expected period of performance.	The Small Unit Leader does not request heavy weapons squad within the expected period of performance.	The Small Unit Leader requests heavy weapons squad when it is not needed.	
1.3.4	The Small Unit Leader identifies a suitable Base of Fire (BOF) location.	The Small Unit Leader does or does not order a Squad to establish a base of fire.	E: Sound Cue or Visual Cue A: Message Sent	The Small Unit Leader orders a Team to a location that will be a Base of Fire.	The Small Unit Leader does not order a Squad to base of fire position within the expected period of performance.	The Small Unit Leader orders a Team to a poor Base of Fire position.	
1.4	The Small Unit Leader can approach and clear a building.	N/C					
1.4.1	The Small Unit Leader can approach a building to be cleared.	N/C					

LO ID	LO Description	Coaching Notes	Supporting Sim Message	Target Description	BugA Description	BugB Description	BugC Description
1.4.1.1	The Small Unit Leader knows to move a team to assault position outside the building.	The Small Unit Leader does or does not order a Team to move to assault position. N/C	E: Scenario Initialization Data A: Message Sent	The Small Unit Leader orders a Team to assault position within the expected period of performance.	Small Unit Leader does not order Squad to assault position within the expected period of performance.	The Small Unit Leader moves a Team to a poor assault position.	
1.4.1.2	The Small Unit Leader knows the proper use of cover and concealment.	N/C					
1.4.1.2.1	The Small Unit Leader uses smoke to conceal move when appropriate.	The Small Unit Leader does or does not employ smoke when it is available and feasible.	E: Scenario Initialization Data A: Message Sent	The Small Unit Leader correctly uses smoke to conceal movement when it is appropriate and available.	The Small Unit Leader does not use smoke when it is available and suitable.	The Small Unit Leader uses smoke when it is unsuitable.	
1.4.2	The Small Unit Leader can order an assault team to enter the building.	N/C					

LO ID	LO Description	Coaching Notes	Supporting Sim Message	Target Description	BugA Description	BugB Description	BugC Description
1.4.2.1	The Small Unit Leader knows when to order the assault team to enter a building.	The Small Unit Leader does not order the entry of the building when authorized.	E: Incoming Message A: Message Sent	The Small Unit Leader gives the proper order to enter the building within the expected period of performance.	The Small Unit Leader does not give the order to enter the building within the expected period of performance.	The Small Unit Leader gives the order to enter the building before the Fire Team signals it is ready.	The Small Unit Leader gives the order to enter the building without authorization.
1.4.2.2	The Small Unit Leader knows how to order the assault team to enter a building.	The Small Unit Leader does not correctly order the entry of the building.	A: Message Sent	The Small Unit Leader uses the correct communication mechanism when issuing orders to the subordinate.	The Small Unit Leader gives no orders within the acceptable period of performance.	The Small Unit Leader uses an inappropriate communications technique.	
1.4.3	The Small Unit Leader can correctly enter a room being cleared.	N/C					

LO ID	LO Description	Coaching Notes	Supporting Sim Message	Target Description	BugA Description	BugB Description	BugC Description
1.4.3.1	The Small Unit Leader can appropriately enter a room during a building clearing operation.						
1.4.3.1.1	The Small Unit Leader knows when to enter the room.	The Small Unit Leader does or does not enter the room at the appropriate time.	E: Incoming Message A: Message Sent or Unit Movement or Unit Arrival	The Small Unit Leader enters the room within the acceptable period of performance.	The Small Unit Leader does not enter the room within the acceptable period of performance.	The Small Unit Leader enters the room when it is inappropriate to do so.	
1.4.3.1.2	The Small Unit Leader knows how to enter the room.	The Small Unit Leader does or does not enter the room using the correct entry technique.	A: Message Sent or Unit Movement or Unit Arrival	The Small Unit Leader enters the room using the correct technique within the acceptable period of performance.	The Small Unit Leader does not enter the room within the acceptable period of performance.	The Small Unit Leader enters the room using an incorrect technique.	The Small Unit Leader flags himself while searching the room.
1.4.3.2	The Small Unit Leader visually sweeps room upon entry.	The Small Unit Leader does or does not visually sweep the room completely upon entering.	E: Room Entered A: Object Visibility	The Small Unit Leader visually scans the entire room within the expected period of performance.	The Small Unit Leader does not visually sweep the room within the expected period of performance.		

LO ID	LO Description	Coaching Notes	Supporting Sim Message	Target Description	BugA Description	BugB Description	BugC Description
1.4.3.3	The Small Unit Leader knows the ROE regarding the use of weapons during building clearing.	N/C					
1.4.3.3.1	The Small Unit Leader engages enemy, if any, IAW ROE, upon entering a room.	The Small Unit Leader does or does not engage enemy combatants in the room upon entering.	E: World Object & Scenario Initialization data A: Friendly Fires	The Small Unit Leader engages an enemy combatant in accordance with the Rules of Engagement.	The Small Unit Leader shoots when it is unnecessary.	The Small Unit Leader does not shoot when it is necessary.	
1.4.3.3.2	The Small Unit Leader does not engage unarmed civilians upon entering a room.	The Small Unit Leader does or does not engage unarmed civilians in the room upon entering.	E: World Object & Scenario Initialization data A: (absence of) Friendly Fires	The Small Unit Leader does not engage unarmed civilians upon entering a room.	The Small Unit Leader engages unarmed civilians.		
1.4.3.4	The Small Unit Leader correctly directs subsequent team members regarding entering the room.	The Small Unit Leader does or does not correctly direct the next team member into the room when appropriate.	E: Incoming Message A: Message Sent or Unit Movement or Unit Arrival	The Small Unit Leader directs subsequent team members correctly within the acceptable period of performance.	The Small Unit Leader does not order the next team member into a room, when they are needed, within the acceptable period of performance.	The Small Unit Leader orders a team member into a room when there is no need.	

LO ID	LO Description	Coaching Notes	Supporting Sim Message	Target Description	BugA Description	BugB Description	BugC Description
1.4.4	The Small Unit Leader can manage subsequent room clearings	N/C					
1.4.4.1	The Small Unit Leader marks, or orders marked, the cleared room with a Wolf's tail.	The Small Unit Leader does or does not ensure that a cleared room is marked with a wolf tail.	See "SITREP discussion above for additional information. E: Object Visibility A: Message Sent or Wolf Tail Deployment message	The Small Unit Leader ensures a cleared room is correctly marked within the expected period of performance.	The Small Unit Leader does not ensure a cleared room is marked within the expected period of performance.	The Small Unit Leader orders a room to be marked that has not been cleared.	
1.4.4.2	The Small Unit Leader orders Trail Fire Team into the building and to the entrance to the next room.	The Small Unit Leader does or does not order the next Squad into position to clear the next room.	E: see SITREP discussion for cleared room conditions A: Message Sent	Small Unit Leader orders the trail fire Squad into the building within the expected period of performance.	Small Unit Leader does not order the trail Fire Team into the building within the expected period of performance.	Small Unit Leader orders the trail Fire Team into the building prematurely.	
1.4.4.3	The Small Unit Leader rotates Fire Teams roles during multiple room clearing operations.	The Small Unit Leader does or does not alternate Fire Teams when clearing multiple rooms.	E: implicit requirement coded into Coach A: Message Sent	The Small Unit Leader alternates which fire Squad enters a room first as multiple rooms are cleared.	The Small Unit Leader always uses the same fire team to enter a room first across multiple rooms.		

LO ID	LO Description	Coaching Notes	Supporting Sim Message	Target Description	BugA Description	BugB Description	BugC Description
1.5	The Small Unit Leader can deal with complicating factors	N/C					
1.5.1	The Small Unit Leader can deal with wounded civilians.	The Small Unit Leader orders medical treatment or evacuation for the civilian	E: Scenario Initialization data or World Object A: Message Sent	The Small Unit Leader has ordered the evacuation and medical treatment of wounded civilians within the expected period of performance.	The Small Unit Leader does not order the evacuation of wounded civilians within the expected period of performance.	The Small Unit Leader has not ordered medical care for wounded civilians.	
1.5.2	The Small Unit Leader can deal with visual obstructions in a room.	The Small Unit Leader does or does not "look behind" the obstruction.	E: Scenario Initialization data or World Object A: Object Visibility	The Small Unit Leader visually examines the entire room including areas visually blocked by objects in the room within the expected period of performance.	The Small Unit Leader does not visually examine the room within the expected period of performance.	The Small Unit Leader does not visually examine the room areas blocked by objects.	

LO ID	LO Description	Coaching Notes	Supporting Sim Message	Target Description	BugA Description	BugB Description	BugC Description
1.5.3	The Small Unit Leader can order security for building occupants when needed.	The Small Unit Leader does or does not order the person to be watched.	E: Scenario Initialization data or World Object A: Message Sent	The Small Unit Leader orders someone to provide security for the person within the acceptable period of performance.	The Small Unit Leader does not order someone to provide security for the person within the acceptable period of performance.		
1.5.4	The Small Unit Leader can deal with the discovery of weapons/ordnance in the building.	The Small Unit Leader does or does not order the materials to be secured or removed.	E: Scenario Initialization data or World Object A: Message Sent	The Small Unit Leader orders weapons and ammunition discovered in the room to be safeguarded and removed from the area within the expected period of performance.	The Small Unit Leader does not issue the proper orders regarding weapons and ammunition discovered in the room within the expected period of performance.	The Small Unit Leader issues incorrect orders regarding weapons and ammunition discovered in the room.	

APPENDIX B

Trigger Analysis

The following table includes the Trigger Analysis, which presents the Coach component's requirements for information from the simulation environment. The first column indicates what type of message is described, Expectation ("E"), Action ("A") or Outcome ("O"). The distinction between them is sometimes arbitrary, but generally speaking, Expectation messages tell the Coach about the world, Action messages tell the Coach about actions taken by the user and Outcome messages include items that do not fit cleanly into either category, such as timer "heartbeat" messages that keep the Coach informed about the passage of time in the simulated world. The next column "Message" is a short description about what the message from the simulation is intended to communicate. The "Trigger" column describes when or under what conditions the message should be sent to the Coach component. The next column "Data Items" provides a description of what specific information the Coach needs. The last column "Comment" provides either an explanation about what the data will be used for or documents unresolved issues about the data or message contents.

Type	Message	Trigger	Data Items	Comment
O	Cover object information	<p>This message should be sent at the start of the scenario, and we will explicitly design the scenario to only require the creation of a manageable amount of cover objects. We will include a small number of suitable cover objects with one object that is unsuitable. Objects that are created for visualization only are non-interactive. Non-interactive objects do not have types (e.g., terrain, buildings, trees, rocks and essentially do not exist).</p>		<p>This message may be merged into the "World Object" message below if all the information described here is provided.</p>
			Type of object	<p>For the cover objects specified as part of the scenario design, provide a type specifier.</p> <p>Interactive objects have type information (e.g., people, vehicles, rocks, trees).</p>

Type	Message	Trigger	Data Items	Comment
				<p>A Boolean value indicating whether the object will provide cover for the Soldier. Not sufficient for long term use, but sufficient for a limited set of scenarios, where the specific weapons in use by the enemy are known.</p> <p>A future capability, that is, beyond Phase II, could include more fine-grained gradations such as what caliber bullet could be stopped and/or what kind of round could be stopped by a polygon.</p>
			The cover it provides	

Type	Message	Trigger	Data Items	Comment
				<p>Location should be provided in the coordinates of the world.</p> <p>Planar size means the size of the object relative to a specific geometrical situation. That is, based on an enemy line of sight, what is the extent of the object perpendicular to the line of sight that could be used for cover?</p> <p>Make simplifying assumption that enemies do not move during scenario. This allows for planar objects to exist in size and location AND relative to each enemy. Thus, we will have one instance of object with multiple representations, one for each enemy's perspective.</p>
			Location and planar size	
			Size	This object no longer needed based on information that the previous data item is providing.

Type	Message	Trigger	Data Items	Comment
O	World Object information	AIS can decide whether there should be multiple messages for Cover Objects, for World Objects and for Room Objects. We could merge these messages into a single object message.		This message is to establish objects in the scenario such as occupants and ordnance.
			Type of object	Information regarding what the object is.
			Object attributes	This item must provide whatever attributes are needed by the Domain Expert, such as the classification of a building occupant.
			Location of object	This information is needed in world coordinates and also in human readable form (e.g., "northeast of building 34", or "room 4")
			Object Instance	There is the need for an object instance in this message.

Type	Message	Trigger	Data Items	Comment
		This will be a scripted communications message, amounting to telling the squad that they have been seen, based on some intelligence.		
O or E	Enemy to friendly visibility	This message must be sent when the enemy comes into view and goes out of view, with a flag indicating which condition is being transmitted.		
			Friendly unit designator	As defined in scenario.
			Enemy unit designator	As defined in scenario and consistent with proper Army designation of enemy units.
			Visibility Indication	An indication of how the visibility was achieved (e.g., visual, IR). These data should support the case if more than one method of visibility was achieved.

Type	Message	Trigger	Data Items	Comment
		Soldier sends a message		
A	Message Sent	Use some form of GUI-based communication approach. We do not want to create pop-up screen entities, so we might wish to allow a single keyboard action to provide the indication of a message being sent. This is useful for the desktop system because the immersive system requires and allows different solutions.		
			From	Which friendly unit sent the message, using unit designator and also human readable form
			To whom sent	To which friendly unit was the message sent, using unit designator and also human readable form
			When sent	Real world time when the message was sent
			Content	Type of message and the contents about which we can know

Type	Message	Trigger	Data Items	Comment
			Form	What message type was sent (e.g., Contact, SITREP)
			Delivery mechanism	Radio, voice, hand signals.
A or O	Unit movement	When unit begins moving using existing DIS PDU triggering parameters		Based on types of movement techniques and formations. The humans will use the message sending process to identify which technique and formation they selected.
			Which unit	Friendly unit designator
			Starting location	The starting location should be known from the friendly unit status.
			When movement started	Real world time when movement was initiated.

Type	Message	Trigger	Data Items	Comment
O	Visual Cue	<p>When a visual cue is presented to the user.</p> <p>Only use this for indications of enemy activity which are transient in nature (e.g., muzzle puff, muzzle flash, round impact).</p>		Pixel rendering discovery is not practical, however, the point rendering technique could be useful in this case as well (see the Visibility items discussion). The visual cues are mostly events that require “scripted” animation events, making the point rendering technique manageable.
			Real world location	This information is needed for two reasons: a 3-space vector relative to the Soldier’s actual position and also in some form that can be used to tell the Soldier where something was hidden.
			Rendered on display	Yes or no, it may be that for the desktop version of SVS a no means the message is not sent.

Type	Message	Trigger	Data Items	Comment
			Field of view location	Relative to the center of the display, that is, since this version of the VOC is desktop based, how close to the center of the computer monitor the entity was drawn is useful in determining how sure the system can be that the Soldier should have seen it.
			Size information	How many pixels or some category regarding visibility (e.g., barely visible, visible, obvious), to be used as a mechanism to decide how likely the visual cue could have been seen by the Soldier.
			Duration information	How many seconds the object was visual on the display in seconds.
			What was rendered	An indication of what was rendered (e.g., "dust kicked up by round impact", "muzzle flash").

Type	Message	Trigger	Data Items	Comment
A	Room entered	When element enters room: This message is only provided for human Soldiers.		
			Friendly element designator	From scenario definition.
			To Room identifier	From world object information provided
			From Room Identifier	
		A predetermined list of objects that can be placed in a room will trigger this message when a friendly human Soldier sees them. The objects include a container of weapons or ordnance.		This message will be used to handle searching a room. The notion of an invisible object behind a visually obstructing object in a room will be used to provide an indication that the human Soldier searched the room thoroughly. That is, if they never see the invisible object placed behind the couch, then they have not adequately searched the room.
O	Object Visibility			

Type	Message	Trigger	Data Items	Comment
O	Heartbeat Message	Sent Periodically at a configurable rate, probably around every 3 to 4 seconds.		
			Simulation Time	

APPENDIX C

Feedback Samples

The following table shows an extract of the feedback development document. Due to the fairly complex nature of defining multiple synonymous feedback messages for any specific Soldier behavior, mapping each behavior to the Cognitive Model and to the Coach software, there are two table heading rows necessary. The first heading row provides the mapping between the feedback messages and the Cognitive Model by indicating what the Hierarchical and Unique identifiers are. These two identifiers are created as part of the Cognitive Model development work and are referenced in this table to allow verification that the feedback messages are dealing with the correct Soldier behavior. The second heading row, the one with “Target,” “BugA,” etc. allows for the mapping between the feedback messages and the Coach software. The feedback messages discuss either correct or incorrect behaviors, and because there is usually more than one incorrect behavior, the “A” “B” designations for the incorrect behaviors allow for the mapping of a particular set of messages to the specific Coach assessment functionality.

Unique ID	Hierarchical ID Target Description		Bug Descriptions	
UID 123	WBS 1.1.1.1	Variables: Voice Message From Student Contact Report		
	Target	Bug A	Bug B	Bug C
	The Small Unit Leader either attempts to send or does send a Contact Report to the Platoon Leader within the acceptable period of performance.	The Small Unit Leader does not report to the Platoon leader within the acceptable period of performance.	The Small Unit Leader sends the wrong report type.	The Small Unit Leader sends a Contact Report when there was no reason to.
High	You just sent a good Contact Report.	All Contact Reports need to be sent as soon as possible.	You sent the %PhraseRcv%, but you should have sent the %PhraseExp%. Check your type of report before you send it.	Why did you send that Contact Report?

Unique ID	Hierarchical ID Target Description		Bug Descriptions	
		Send your Contact Report as quickly as possible.	Make sure you check your report before sending it. You sent the %PhraseRcv%, but you should have sent the %PhraseExp%.	
Low	Good job!	Your Contact Report is late.	Did you send the correct type of report?	Don't send reports that aren't required.
		Don't wait to send a Contact Report.	Were you supposed to send a Contact Report?	

APPENDIX D

AAR Data Description

This appendix describes the data generated by the Coach component and used by the Analytical AAR component. These data reside in two separate repositories, one is the Unified Learner Model (ULM) and the other is a data store specifically designed to support the detailed AAR reporting described above and known as the Expectation and Evidence (EE) data store. The ULM is described in the following Appendix. This Appendix describes the EE data store.

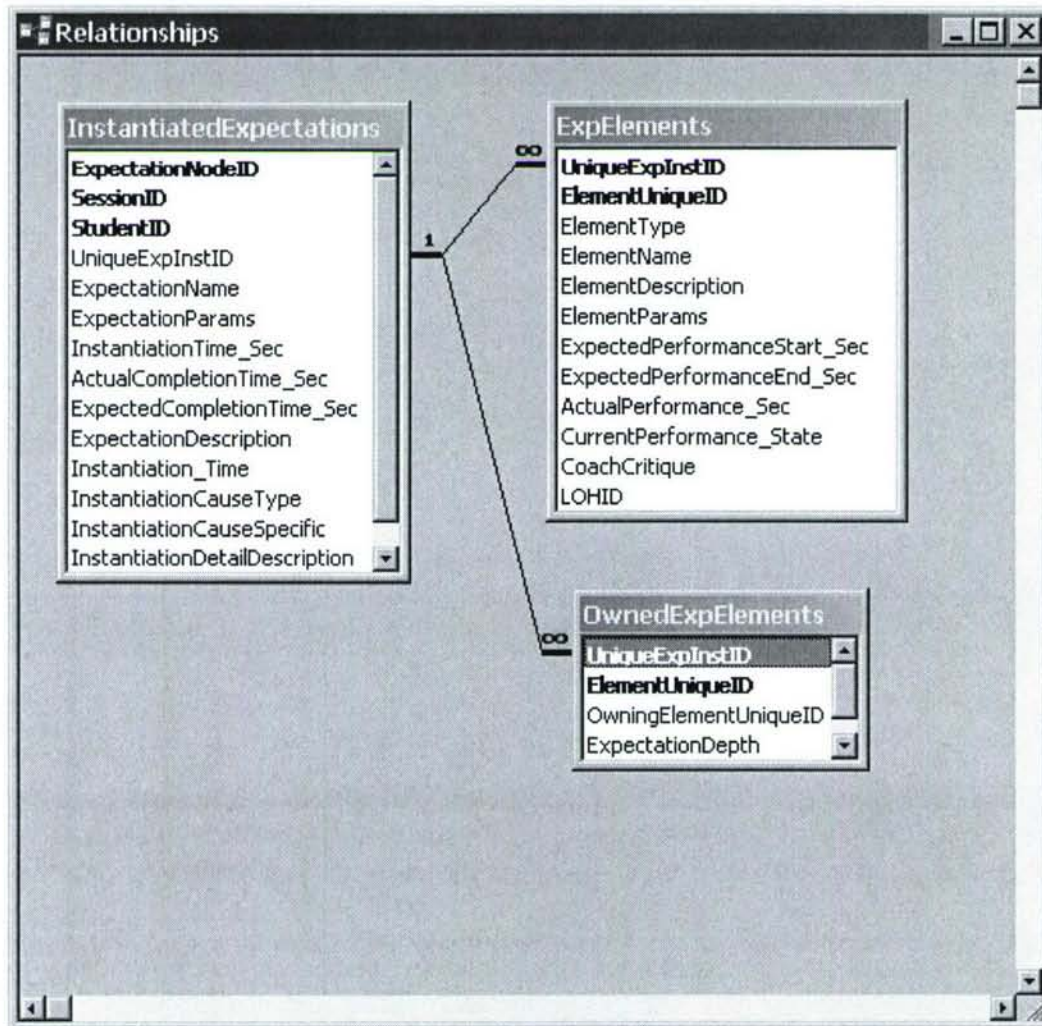
The following figure depicts the relationships among the various tables in the Expectation data store. There are two broad categories of information in this data store: 1) Evidence and 2) Expectation instances. The following figure depicts the relationships among the various tables for the Expectation instances data. The evidence category includes all the individual Coach assessment decisions and the related contextual information. For example, if the Coach determined that a Soldier was late in acknowledging an order while waiting to begin the approach to the building, then the recorded evidence would include the following information:

Data Item	Example Value
Student ID	Fire Team A Leader
Owning Expectation	Approach Building
Specific Expected Action	Order Acknowledgement
Learning Objective	1.2.3.1
Polarity of Assessment	Negative
Category of Performance	Bug
Specific Performance	Late
Feedback Provided	Yes
Feedback	“Why didn’t you acknowledge your order?”

The relationship figure below indicates that there are many more data items than shown in the table above, but many of these are used to manage the relationships among the tables. Additionally, not all the fields being recorded are being used in the current version of the VOC or the Analytical AAR component.

The second category of information is Expectation Instance information. This data store records every Expectation instantiated by the Coach along with all the details regarding the required specific Soldier actions for each Expectation. In the Evidence example depicted above, the following information, shown in a simplified fashion, would have been recorded in the Expectation tables:

Data Item	Sample Value
Expectation Name	Approach Building
Expectation Element Type	Voice Response
Element Period of Performance	20 seconds
Actual Period of Performance	25 seconds
Element Data	Acknowledge order
Element Description	Soldier knows to respond to order



APPENDIX E

Unified Learner Model

The Unified Learner Model captures what is known about the Soldier in what is known as a mastery profile. The goal of the mastery profile is to document the Soldier's current level of understanding of the instructional material. There are four classes of learner models that are commonly used:

- Performance models,
- Overlay models,
- Error models, and
- Simulation models

The VOC uses an Overlay model. This approach represents the Soldier's knowledge as a sub-set of an expert's. Overlay models present an expert's knowledge as a collection of concepts, represented as a tree of learning objectives. They then record the Soldier's mastery, or lack thereof, of each learning objective. The overlay model allows determining specific areas of strength and weakness for each Soldier by storing "mastery data," described below, for each individual learning objective.

The mastery data are based on the summation of positive and negative endorsements accumulated during training sessions. The "raw" endorsements are the direct result of each Coach software assessment conclusion about a Soldier's specific actions. Each of these Coach assessments map to a single learning objective. Thus, when the Soldier fails to respond correctly to a superior's order to enter a room, the learning objective associated with knowing when to enter a room receives a single negative endorsement. This endorsements process is also called direct evidence. However, within the ULM, there are also mastery data that are inferred from the learning objectives that receive direct endorsements. While this mastery evidence is considered to have a lower reliability than direct evidence, it will be visible in the mastery data. This evidence is sometimes referred to as indirect or inferred mastery. These indirect mastery data do not affect the mastery of any learning objective for which there is direct evidence. They only affect the parent or children nodes of directly endorsed learning objectives. There are two broad categories into which the mastery evidence can be placed:

- Non-Performance – Indirect or inferred mastery.
- Performance – Direct evidence related to actual student behavior.
-

Indirect mastery processing is referred to a "bubbling" and takes the following four forms:

- Data Trend - Affected by consecutive "Performance" endorsements on a given node.

- Propagated Disbelief - Occurs when the net of any child node becomes negative.
- Label Trend – Used when all child nodes of a parent have the same polarity. This endorsement is made only on the transition defined when the last child node becomes positive or the first to become negative.
- Inherited Belief - This is an endorsement to a child or children of a parent node when a parent becomes positive. All the children receive a positive endorsement at this level.

Bubbling amounts to accumulating and retracting these indirect evidence types according to the rules shown in the following table.

Category	Type	Accumulation Rule	Retraction Rule
Data Trends	Non-Performance	The sum of the positive and negative counts is less than or equal to one. An endorsement is based on a consistent trend across performance categories for a given node.	Retract a trend endorsement if the trend is broken by a counter endorsement from a performance source (e.g., after a string of correct performances, the student answers a question incorrectly).
Propagated Disbelief	Non-Performance	Positive count is always 0. Negative count is 0 or 1	Retract when conditions of the children nodes no longer support the disbelief.
Label Trend	Non-Performance	The sum of the positive and negative counts is less than or equal to one.	Retract when condition of the children nodes no longer support the trend.
Default Belief	Non-Performance	The sum of the positive and negative counts is less than or equal to one.	No Retraction is necessary.

APPENDIX F

VOC Scenario Details

This Appendix provides additional detail on scenarios used in the VOC. Notionally, there is one basic building clearing scenario with several variations introducing differing building contents. The following table summarizes the scenario contents.

	Comment
Scenario One	Uncomplicated Building Clear
Scenario Two	A civilian exists in one of the rooms
Scenario Three	A wounded civilian exists in one of the rooms
Scenario Four	An armed person is present in one of the rooms, but does not shoot at the fire team when it enters the room.
Scenario Five	An armed building occupant fires at a fire team as they enter a room
Scenario Six	Incoming fire is received as one of the fire teams. This scenario requires at least two cover objects, one close at hand and one more distant from the building..
Scenario Seven	There is some ordnance in one of the rooms where it can be discovered by a fire team
Scenario Eight	There is ordnance in a room, but it is visually obscured from the perspective of the room entrance by a visual obstruction such as a large piece of furniture.
Scenario Nine	There is a hostile, armed occupant in the building, hiding behind a visual obstruction

A Deployed VOC Narrative

2LT Thomas is a new Platoon Leader (PL) in 2nd Platoon, A Company, 2nd Battalion, 502nd Infantry. 2LT Thomas has several new Squad Leaders (SL) in his platoon. 2LT Thomas decides to take advantage of a new training opportunity at his base. He decides to send one of his SL and two of his fire team leaders to a virtual training facility. 2LT Thomas suggests that the squad conduct an exercise. One SL and two fire team leaders prepare to practice maintaining their situational awareness during a simulated exercise. One of the Soldiers puts on his virtual reality helmet and steps into the system, while the two other men sit down at personal computers. The Soldiers log in, and the VOC retrieves their individual learning profiles. The VOC selects the best scenario for the Soldiers. The scenario selected is a building-clearing scenario that focuses on situational awareness and that sharpens room clearing tactical skills. The VOC asks the Soldiers if they want to do this exercise with other Soldiers from other units or use computer-generated forces for their other team members. The Soldiers

choose to work with the computer-generated forces because they are just getting used to working together as a squad.

The squad receives a mission briefing stating that they are to conduct a dismounted patrol. The scenario places the squad on the streets of Baghdad in the early days after its capture. After reviewing their ROE, the men see that they are actually in a street in Baghdad. They are part of a platoon, but the only Soldiers that are visible right now are the nine members of this squad. The other squads consist of computer-generated forces.

The SL issues an order to use bounding overwatch and to proceed up both sides of the street. The VOC notes that the SL has used the correct formation and movement technique. After a few minutes, a shot rings out. While most of the men immediately move to cover, the VOC notes that the Alpha team leader took cover behind several 55-gallon drums. The voice of the PL plays in the team leader's headset telling him to seek real cover, not just concealment. Meanwhile, the SL is trying to determine if anyone knows where the sniper is, and verify that there were no casualties. One of the squad members says that he saw a sniper in the second floor window of a building in front of them. The SL reports to the PL and receives orders that the platoon is going to clear the suspected building. His squad is told to establish a base of fire. The SL directs his men to occupy positions to provide suppressive fire. The voice of the PL tells the SL that he should have taken a better look at the area and selected positions that allowed them to isolate the building and cover the window where the sniper was seen. The SL directs the Alpha team leader to a new position, and orders Bravo team to cover Alpha team's movement.

The squad hears on the platoon net that another squad is getting into position on the other side of the building. The Alpha team leader sees an enemy Soldier in a different building. He reports to his SL that he sees enemy movement, and the SL sends the PL a contact report. The VOC recognizes that an important piece of information was not in the SL's report. The SL did not give the direction of movement of the enemy. This is a crucial piece of information because the enemy was moving in the direction of the building that the platoon is going to clear. The VOC decides to pause the simulation while each Soldier is given a situational awareness assessment. Each Soldier is shown a map of the area and is asked to indicate on the map where friendly units are, where enemy units are, where the most vulnerable and strongest positions are for both sides. After this brief individual situational awareness assessment the VOC sees that the SL did not realize that a given sector was vulnerable, whereas the Alpha team leader did. The VOC decides not to tell the squad about this discrepancy, but saves this information for the AAR. The VOC resumes the training exercise after everyone has finished the situational awareness assessment.

Next, the squad hears over the radio that that another squad has breached the building and has secured a foothold. The PL orders the 1st squad to enter the building to clear it. The SL reminds his team that they will be using the strong wall as opposed to the opposing corners method of placing men into position in rooms. Once they have

cleared a room, the SL makes an error of not correctly marking all the exits, and the VOC reminds the SL to do this correctly. The fire team leaders are occasionally reminded to not to stop and shoot while they are standing in a doorway.

At the end of this 15-minute exercise, the VOC conducts an AAR. The VOC begins the AAR and focuses on the team's lack of shared situational awareness. All the Soldiers are asked to write a few sentences summarizing what they think happened. After everyone has written their own explanation the VOC shares what it thinks caused the problem (the fire team failing to report that enemy were moving towards the building.) The Soldiers are then able to discuss this problem. The Soldiers' explanations and conversations are recorded, but not analyzed by the VOC. The SL is asked by the VOC to explain why he chose the sequence of rooms to clear that he did. The SL is presented with a system of menus to help elicit the reasons for his choices. The SL is also told that he should swap out his lead teams more often. The Soldiers can decide to do another training exercise and the VOC will select another scenario for them.

APPENDIX G

ASR Grammar Discussion

Grammar Structure

The VOC ASR system takes advantage of the highly structured nature of military communications. The highest level of the ASR grammar resembles this:

<Statement> -> <Recipients> <Sender> <Action> <Out>

An example phrase that fits this grammar is, “Red One One Alpha, Red One One, approach building alpha, over.” The various parts of the phrase are examined in detail below.

Sender and Recipients

The <Sender> and <Recipients> tokens identify who is sending the message and who is/are the intended recipient(s) of the message, respectively. These tokens translate to various call signs. Currently, there are enough call signs recognized for a two-squad exercise. The call signs are enumerated below (indented call signs are synonyms for the corresponding call sign above, so “Red One”, “Papa Lima”, and “P L” all refer to the same unit).

Red One	(Platoon Leader)
Papa Lima	
P L	
Red One One	(1 st Squad Leader)
One Sierra Lima	
One S L	
Red One One Alpha	(1 st Squad, Fireteam A Leader)
Red One One Alpha Two	
Red One One Alpha Three	
Red One One Alpha Four	
Red One One Bravo	(1 st Squad, Fireteam B Leader)
Red One One Bravo Two	
Red One One Bravo Three	
Red One One Bravo Four	
Red Two One	(2 nd Squad Leader)
Two Sierra Lima	
Two S L	

Red Two One Alpha (2nd Squad, Fireteam A Leader)
 Red Two One Alpha Two
 Red Two One Alpha Three
 Red Two One Alpha Four

Red Two One Bravo (2nd Squad, Fireteam B Leader)
 Red Two One Bravo Two
 Red Two One Bravo Three
 Red Two One Bravo Four

There can be one sender and up to three recipients in a given utterance. If only one unit ID is given, then it is assumed to be identifying the recipient, unless it is prefixed with “I am” or “this is”, for example:

“Red one one bravo, red one one ...”	Red11 talking to Red11B
“Red one one bravo, this is red one one ...”	Red11 talking to Red11B
“Red one one alpha, red one one bravo, red one one ...”	Red11 talking to Red11A and Red11B
“Red one one alpha ...”	Unidentified unit talking to Red11A
“This is red one one alpha ...”	Red11A talking to an unidentified unit

Actions

The Action token forms the bulk of most communications. Of the three Statement tokens, it is also the most complex token, resulting in a wide variety of potential statements to recognize. We will begin by breaking down the Actions into their various components.

Actions can be broken down into three classes of possible communication types. These classes are Orders, Reports, and Requests (queries). Orders are typically tasks or actions given to subordinate units to carry out, such as movement orders and fire orders. Conversely, reports are usually sent up the chain of command to superior units. These include contact reports, set reports, and situation reports (SITREPs), general acknowledgements (“roger”) also fall into this category. Requests or queries typically come from superior units, and are used to explicitly request reports from subordinate units (“red one one alpha, red one one, give me a sitrep, over”). These three action classes will be examined in detail in the following sections.

Orders

There are nine types of order recognized by the ASR grammar. These are move, assault, fire, marking (wolf tail), clear building, clear room, transport, take cover, and security. Each of these order types can have various optional components added to it. For example in the case of a move order, consider the following possibilities:

Red One One Alpha, Red One One, move, over.
 Red One One Alpha, Red One One, move double-time, over.

Red One One Alpha, Red One One, move to your right, over.
 Red One One Alpha, Red One One, move southwest fifty meters, over.
 Red One One Alpha, Red One One, move fifty meters southwest, over.
 Red One One Alpha, Red One One, move to building three, over.
 Red One One Alpha, Red One One, go to building three, over.
 Red One One Alpha, Red One One, approach building three, over.
 Red One One Alpha, Red One One, move to building three double-time, over.
 Red One One Alpha, Red One One, move to building three by bounding overwatch, over.
 Red One One Alpha, Red One One, move to fifty meters southwest of building three, over.
 Red One One Alpha, Red One One, move your team to building three, over.
 Red One One Alpha, Red One One, move your team to fifty meters southwest of building three by bounding overwatch, over.

As you can see, there are many variations of the move order, and of all the orders in general. Indeed, there are many more possibilities than just those enumerated above. Rather than enumerate every possible statement, this section will provide the general framework for each of the orders and give a few examples (like those above) of how they may be used. These frameworks are composed of various components, some of which are required, and some of which are optional. To denote which components are required, we will use angle brackets < >, and to show optional components, we will use parentheses.

Some tokens are fairly simple, but have synonyms. For example, wherever you see the token < the >, the words “the,” “that,” “these,” and “those,” will all be recognized.

Move Orders

Move orders follow one of the following formats:

```

<Move> ( Movable Entity ) ( Location ) ( Move Modifier ) ( Condition )
<Evacuate> ( from ( Location ) )
<Enter> ( the ) < Building > ( Location Modifier )
<Enter> ( the ) < Room > ( Location Modifier )
  
```

The first format is the basic move order. Examples of this format are given in section 2.2.1 above. The “Move” token is the only required element and can be any of the following:

```

move
move to
go
go to
approach
  
```

The “Movable Entity” token modifies the move command to indicate what should be moved. Movable entities include the Soldier’s own team members, captured enemy forces, civilians and other neutrals, and objects in the environment, such as weapons or ordnance that the team may find during room clearing. Some examples of movable entities are:

your team	ordnance
your man	equipment
the wounded	ammo
civilians	ammunition
women	missile
children	missiles
non combatants	R.P.G.
hostages	arms cache
op for	weapons cache
enemies	explosives
	barrels

The “Location” token allows a specific location to be added to the move order. Location is a more general concept that applies to many kinds of orders, so it will be covered in a separate section below.

The “Move Modifier” allows the kind of movement to be specified. Currently only “double-time” and “bounding overwatch” are accepted as movement modifiers.

The “Condition” token allows the user to specify a condition, or trigger for the movement. Possible conditions are command conditions, time conditions, and event conditions. Command conditions include “on my command,” “on my mark,” “on my signal,” or “on my order.” Time conditions simply specify a time to wait before moving. For example, “move to building three, time now,” “move to building three after ten minutes,” or “move to building three at thirteen hundred.” Event conditions specify an event that should occur to trigger the movement. Currently, the only event recognized is something of the form <Unit> is <Set>, such as “move to building three when Red One One Bravo is set,” or “when Red Two One is in position.”

The remaining three move order forms are simpler. The evacuation order begins with one of the following commands:

exit
leave
retreat
withdraw
evacuate
get out

It terminates with any location. The remaining two forms are entry commands and are identical, except for the target of the movement (either a building or a room). The possible movement targets are given below (buildings on the left and rooms on the right). These targets provide examples of possible movement targets. They are not likely to be a complete set of possibilities for any scenario, and the list will need to be modified as new scenarios are developed.

building	room
building alpha	room one
building bravo	room two

building charlie
tower
water tower
hotel
school
church
mosque
yellow building
red building
blue building
green building
two story building
long building
steeple
fenced in building
building behind the fence

room three
room alpha one one
room alpha one two
room alpha one three
rooms
alcove
stair well
next room
closet
closets
basement
next room
last room
first room
all rooms

The Location Modifier token for the two entry commands allows a building or room to be specified relative to the user, such as “the building fifteen meters ahead,” or “the room to your right.” This modifier is part of the overall Location token, and will be described in detail later.

Below are some examples of the evacuation and entry orders:

Red One One Alpha, Red One One, exit the building, over.
Red One One Alpha, Red One One, withdraw from the church, over.
Red One One Alpha, Red One One, enter building alpha, over.
Red One One Bravo, Red One One, enter the yellow building to the east, over.
Red One One Alpha, Red One One, enter the room to your left, over.

Assault Orders

The Assault Order takes the form

< Assault > (the) (Location)

The Assault command can be one of the following:

execute assault
assault
attack
occupy

This may or may not be followed by the location. Some examples are:

Red One One Alpha, Red One One, execute assault, over.
Red One One Bravo, Red One One, assault building alpha, over.
Red Two One Alpha, Red Two One, occupy the building, over.

Fire Orders

The Fire Order has two forms:

```
< Fire Command > ( at ) ( Location )  
( Provide ) < Fire > ( at ) ( Location )  
< Fire Command > ( at ) ( Unit )  
( Provide ) < Fire > ( at ) ( Unit )
```

The first two forms recognize the fire command as a verb. The fire command can be one of these:

- fire
- open fire
- shoot
- engage
- bring down

The second two forms recognize a fire order where “fire” is a noun. In this case, the “Fire” token is one of these:

- fire
- suppressive fire
- support by fire
- support with fire
- fire support

In both forms, an optional target or location can also be provided. Both the Unit and Location tokens are fairly complex and will be described in later sections. Below are some sample Fire Orders:

- Red One One, Red One, open fire, over
- Red Two One, Red One, engage opfor, over
- Red One One Alpha, Red One One, provide support by fire on the yellow building, over

Marking Orders

The Marking Order recognizes orders to mark rooms that have been cleared. This is also called the Wolftail Order, after the Wolf Tail, a device used for room marking.

The marking order takes the following form:

```
< Wolftail > ( ( the ) Room )
```

Either “wolftail” or “mark” can be used for the Wolftail command. The “Room” token recognizes the same list of room nouns as given in the Move Order above.

Clear Building/Clear Room Orders

The Clear Building and Clear Room Orders are very similar to the Enter Building and Enter Room Orders given in the Move Orders section above. They are treated as different types of orders by the VOC system, but they are recognized very similarly. The Clear Building order takes the following form:

`< Clear > (the) < Building > (Location Modifier)`

The Clear Room order takes this form:

`< Clear > (the) < Building > (Location Modifier)`

The Clear command can be any of the following:

- clear
- clear out
- go clear

The remaining tokens work identically to their counterparts in the entry commands, as detailed in the Move Order.

Transport Order

The Transport Order is intended to recognize any speech that deals with moving an object or objects from one place to another. Currently the only form this order takes is the Remove Object order, which takes this form:

`< Remove > (all) (the) < Object > (< out of > < Location >)`

The optional predicate allows both “Remove the weapons” and “Get the weapons out of the building” to be recognized.

The Remove command can be any of these words:

- remove
- get
- carry
- carry out

The Object token can be any of these:

- ordnance
- equipment
- ammo
- ammunition
- missile
- missiles

R.P.G.
arms cache
weapons cache
explosives
barrels

Some example Remove Object orders are:

Red One One Alpha, Red One One, remove the weapons from the building, over.
Red One One Alpha Two, Red One One Alpha, carry out the weapons, over.
Red Two One Bravo, Red Two One, get those barrels outside the building, over.

Take Cover Order

This is simply an order for the Soldiers in the unit to find a safe place from enemy fire. It takes the following form:

< Take Cover > (in or behind) (Location)

The Take Cover command can be any of these:

take cover
get down
duck

Security Order

This order is typically issued by a squad leader or fireteam leader for one of the subordinates to provide security on a neutral or a section of the building that is not known to be clear. The format is simple:

< Secure > (the) < Unit >
< Secure > (the) < Location >

For example,

Red One One Alpha Two, Red One One Alpha, secure those civilians, over.
Red One One Bravo Four, Red One One Bravo, provide security on the stairwell, over.

Reports

Like the Order Actions, Reports can be simple or very complex and rich with information. There are three basic types of Report: the Contact Report, the Set Report, and the Situation Report (SITREP). We will detail these three kinds of Reports in the same way as we detailed the Order Actions above.

Contact Reports

This report is sent to a unit's superior when the unit directly encounters an enemy or neutral, or detects their presence indirectly. There are several forms of Contact Report. The first two are used when the team observes the enemy directly.

< Contact > < Location >

< Contact > < Unit > (Detection Description) (Location)

The first form is a simple contact report, describing where the contact is, as in

Red One, Red One One, contact, five meters east of the water tower, over.

The second form is a contact report with the description of the contacted unit, optionally with a description of the detection (movement, smoke, etc), and a location. For example,

Red One, Red One One, contact two opfor in the water tower, over.

Red One, Red Two One, spotted enemy movement south of building three, over.

Red One, Red One One, detected a small group of civilians east of the church, over.

The third form reports incoming enemy attacks, such as

Red One, Red One One, taking small arms fire, over.

Red One, Red One One, taking fire from west of the red building, over.

Red One One, Red One One Alpha, under heavy fire from the hotel, over.

The Contact command can be any of these:

contact
contact report
we have contact
report contact
in contact
in contact with
spotted
detected

The Unit and Location descriptions are complex and will be described in later sections.
The Detection Description can be any of these:

movement
fire
presence
dust

The third form of Contact Report is used when the team is fired upon. It takes this format:

(Self) < Taking > < Attack Description > (Location)

This form begins with an optional “Self” token, which can be expressed as:

I am
we are
I have
we have
I
we

The “Taking” token can be any of these:

- receiving
- taking
- under

The Attack Description can be any of these:

- light fire
- small arms fire
- small amount of fire
- heavy fire
- large amount of fire

Optionally, the word “fire” can be replaced with “attack.”

Set Reports

The Set Report is much simpler than the contact report or SITREP, and has only this form:

(Self) < Set > ((at) < Location >)

The Self token is described in the Contact Report section above. The Set token can be any of:

- in position
- ready
- ready to go
- set
- set to go
- good to go

Situation Report (SITREP)

The SITREP is given in several circumstances, such as when a room is cleared, when an enemy is killed, or when the unit takes casualties. The SITREP has many types and forms. The first type is a casualty report, which has the following forms:

< Self > < has > < KIA >
< Self > < has > < WIA >
< Unit > (is/has) < KIA >
< Unit > (is/has) < WIA >

The "Self" token was described above. The Unit token will be described in a following section. The KIA and WIA tokens are listed below (KIA on the left and WIA on the right):

dead	shot
killed	hit
neutralized	hurt
destroyed	wounded
down	severely wounded
man down	seriously wounded
KIA	WIA

For example,

Red One One, Red One One Alpha, two enemy KIA, over.
Red One, Red One One, we have a man down, over.
Red One One, Red One One Bravo, Red One One Bravo Three is hit, over.
Red Two One, Red Two One Alpha, one civilian dead, over.

Next is an Object Detection report, which is used when items of interest are found (such as enemy weapons caches).

< Detected > < Object > (Location)

The Detected token can be any of the following:

find
found
saw
see
seen
spotted
spot
detect
detected

The Object token is detailed in the Move Order section above, and the Location is detailed in its own section below. Some possible Object Detection reports are:

Red One One, Red One One Alpha, found a missile in room alpha one one, over.
Red One One, Red One One Bravo, spotted weapons, over.

Third is the Room Clear report and the Building Clear report, sent when the squad or fireteam is finished clearing a room or building

(the) < Room > (is) < clear >
(the) < Building > (is) < clear >

The Building and Room tokens are described with the Enter Building and Enter Room Reports in the Move Order section above. The Clear Notice can be either “clear” or “cleared.” For example,

Red One One, Red One One Bravo, room clear, over.
Red One One, Red One One Alpha, the basement is cleared, over.
Red Two One, Red Two One Alpha, building three is clear, over.

Finally, the Location Report gives the position of the unit. This can be used any time the unit needs to report its position to its superior.

(Self) (Location Modifier) < Location >

The Self token is described in the Contact Report above. The Location token at the end will be detailed in a following section. The Location Modifier token can take one of these:

at
on
in
inside
next to
around
vicinity

These are some examples of Location Reports:

Red One, Red One One, we are vicinity building three, over.
Red One, Red Two One, inside the two story building, over.
Red One One, Red One One Alpha, I am fifteen meters east of the water tower, over.

Acknowledgements

Most Orders and Reports must be acknowledged by the recipient for communications to be effective. Acknowledgements are simple, short phrases, and can be any of these:

roger
roger that
roger, understand
understood
understand
I understand
wilco
copy
received
affirmative
yes
yes, sir
go ahead
send it

Requests

Request Actions typically come from higher units and are used to explicitly query information from subordinates. There are also a few requests that are used on both sides, such as for simple communications checking. The various Request Actions are detailed in this section.

SITREP Request

A SITREP Request takes the simple form:

```
( Request ) < SITREP >
```

The Request token is optional and can be any of these:

```
give me  
can you give me  
I need  
request  
requesting
```

The SITREP token can be:

```
SITREP  
a SITREP  
situation report  
a situation report  
a death count  
a body count
```

Examples of a SITREP request are:

```
Red One One Alpha, Red One One, SITREP, over.  
Red One One, Red One, I need a SITREP, over.
```

Set Report Request

Set Report Requests may be used to query the unit if they are currently set, or to have them report that they are set after completing a move order, for example. The following formats may be used for Set Report Requests.

```
< Are You > < Set > ( Location )  
< Report When > < Set > ( Location )
```

For example,

Red One One Alpha, Red One One, are you set, over?
Red One One Bravo, Red One One, report when ready at the yellow building, over.

Acknowledge Request

This is a simple request for an acknowledgement, useful to establish or re-establish communications. Any of these may be used:

come in
do you copy
you copy
you there
acknowledge

Repeat Request

This is a simple request for the recipient to repeat his or her last transmission.

say again
repeat
repeat your last

Medical Assistance Request

This request is sent by a subordinate unit to their superior to dispatch a medical unit. It takes the following form:

< Request > < Medevac > (Location)

For example,

Red One, Red One One, request medevac, over.
Red One One, Red One One Bravo, request medical assistance south of building two, over.

Locations

Locations are complex phrases that may include named places, buildings, rooms, and modifiers such as “inside,” or “to the west of.” Locations can take the following forms:

< Location Prefix > < Named Location >
< Named Location > < Location Modifier >
< Location Modifier > < Named Location >
< Location Modifier >

Named locations can be buildings, rooms, or generic landmarks. Below are the named locations currently recognized by the ASR system:

building	assault area	corner	room
building alpha	rendezvous point	intersection	room a one one
building bravo	evacuation point	street	room a one two
building Charlie	medevac point	road	room a one three
tower	drop off point	up the street	room alpha one one
water tower	rally point	up the road	room alpha one two
hotel	platoon CP	down the street	room alpha one three
school	CP	down the road	rooms
church	checkpoint	first floor	alcove
mosque	assembly area	second floor	stair well
yellow building		third floor	next room
red building		fence	last room
blue building		light post	first room
green building		my position	all rooms
two story building		my location	closet
long building		my current position	closets
fenced building		my current location	basement
		your position	
		your location	
		your current position	
		your current location	

The Location Prefix can consist of any of these items:

- at
- on
- in
- inside
- next to
- around
- vicinity

The Location Modifier has this format:

(Direction Prefix) (Measurement) < Direction > (Direction Suffix)

The following items can be used for the optional Direction Prefix (left column) and Direction Suffix (right column) :

at	here
on	you
from	from you
on your	from your position
to your	me
from your	from me
on my	from my position
to my	us
from my	from us
on our	from our position
to our	from
from our	
to the	

The optional Measurement takes this form:

< 1-99 > < Measurement Units >
< 1 - 9 Hundred > < Measurement Units >

These can be used for the Measurement Units token:

meter
meters
foot
feet
inch
inches
yard
yards

The Direction token can utilize the following directions:

north
northeast
east
southeast
south
southwest
west
northwest
left
right
far left
far right
in front
ahead
in back
behind

The word “of” can optionally be appended to the directions. These constructs can be used to produce the following examples (and many more like them):

Fifteen meters southwest of the water tower
Next to the yellow building
Fifty meters ahead of my position
One hundred meters behind you
At the dropoff point
Southwest of the rally point
Thirty meters down the street
Far left of the two story building

Units

The Unit tokens in the preceding Actions can take the following forms:

< Unit ID >
< Unit Description >
< Quantity > < Unit Description >

The accepted Unit ID’s were given in the Sender and Recipients section.

The Unit Description can take the following forms:

opfor	blue for	civilian	unknown
sniper	friendly	civilians	unknowns
enemy	friendly unit	woman	unknown force
all enemies	your team	women	unknown forces
enemy forces	your man	child	unknown personnel
enemy opfor	the wounded	children	someone
bad guy		kid	
		kids	
		non combatants	
		hostage	
		hostages	

The Quantity field can be any number from one to ninety-nine, or the following quantities:

some
a few
few
lots
lots of
a lot of
a
an
a small group of
a large group of

The following are some examples of units that would be accepted by the ASR system

Red One One Alpha Three
Some civilians
A large group of opfor
Seven enemy
Thirty-two children
A few non combatants
Three hostages
Someone